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Severna Park, MD 21146

RELATIVE MOTION COMPENSATION FOR CARGO HANDLING OPERATIONS -- ANNOTATED BIBLIOGRAPHY

ABSTRACT A literature search was performed to review technical documentation in the area of relative motion. The information obtained from this search was developed into an annotated bibliography. The bibliographies are presented alphabetically, grouped in the following order: relative motion between two ships or craft, relative motion between a ship/craft and a fixed structure, related topics, and a bibliography of additional documents pertaining to the subject.

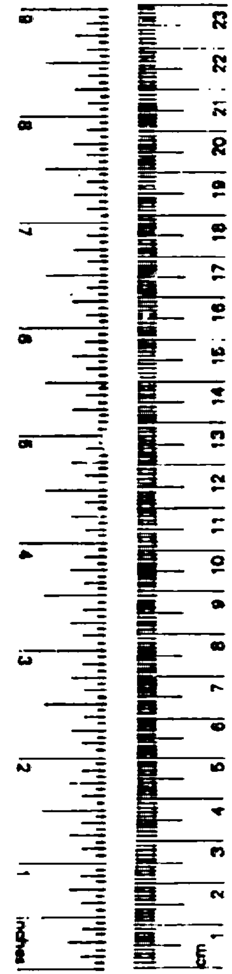
NAVAL CIVIL ENGINEERING LABORATORY PORT HUENEME CALIFORNIA 93043

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

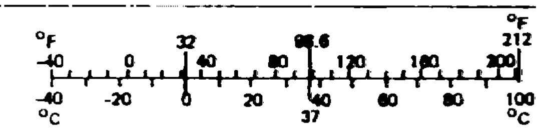
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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13. ABSTRACT *(Maximum 200 words)*

A literature search was performed to review technical documentation in the area of relative motion. The information obtained from this search was developed into an annotated bibliography. The bibliographies are presented alphabetically, grouped in the following order: relative motion between two ships or craft, relative motion between a ship/craft and a fixed structure, related topics, and a bibliography of additional documents pertaining to the subject.

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TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Background

The Logistics-Over-The-Shore (LOTS) mission requires the capability to off-load cargo from government and commercially owned oceangoing vessels onto a variety of lighters for transport to the beach in time of conflict. Cargo operations are affected by the elements of the sea environment and mooring arrangements. Even relatively small waves can induce large motions of the lighter due to the nearness of the large ship or fixed structure. In this type of operational environment, the safety and performance of offshore operations are severely limited by waved induced relative motion between ship and lighter.

In peace time, such a dangerous situation can be usually avoided by stopping the operation. In time of conflict, the troops ashore must be supported. The level of the relative velocities, or more practically, the sea state at which the operation has to be stopped must be decided on. The methods and equipment to meet required operational criteria must be developed. There is a need for innovative techniques to reduce undesirable motions and improve performance of cargo transfer between ship, craft, and fixed platform during cargo transfer operations.

1.2 Scope

A literature search was performed to review technical documentation in the area of relative motion. The information obtained from this search was developed into an annotated bibliography of pertinent information. The bibliographies are presented alphabetically, grouped in the following order: relative motion between two ships or craft, relative motion between a ship/craft and a fixed structure, related topics, and a bibliography of additional documents pertaining to the subject.

Technical publications presented within this report were gathered from military and commercial research organizations, technical societies, and related professional journals. The time range searched was from the present to 1970, although a number of documents, annotated herein, include relevant developments prior to 1970. The following is a partial listing of major organizations searched:

- o Naval Civil Engineering Laboratory (NCEL)
- o David Taylor Research Center (DTRC)
- o Naval Ocean Systems Center (NOSC)
- o Naval Coastal Systems Center (NCSC)
- o Offshore Technology Conference (OTC)
- o American Petroleum Institute (API)
- o American Society of Civil Engineers (ASCE)
- o American Society of Mechanical Engineers (ASME)
- o Society of Naval Architects and Marine Engineers (SNAME)

2.0 RELATIVE MOTION BETWEEN SHIPS

Abkowitz, Martin A., "*Relative Motion Between LCU and Mariner Models in a Seaway,*" Massachusetts Institute of Technology (Oct 1976).

> A program of model seakeeping tests was carried out in the M.I.T. ship model towing tank for the purpose of estimating the relative motion between the deck of an LCU and the top end of a cargo boom on a mariner ship during a typical offshore unloading situation. A five foot long mariner model, scale 1 to 96 (1/8 inch = 1 foot), was available at the tank and the LCU model was built to this scale. Tests were carried out in scaled sea states 3 and 4 which were simulated by irregular seas of the Pierson-Moskowitz spectra representing fully developed seas of wind speeds of 15 knots and 18 knots respectively.

B. C. Research, "*Analysis of the Dynamics of a Motion Compensating Crane,*" B.C. Research Report (Jul 1976).

> This report documents the analysis of a shipboard motion compensating crane for transferring loads from one ship to another in a given sea state. The mother ship, on which the crane is located, is the C4-S-1A Tarheel Mariner, and lighter is the LCM-8. The geometric configuration of the two ships is shown. The crane under consideration is a standard P&H 9125, with fixed boom geometry. The object of this analysis is to specify a control scheme for synchronizing the load motion to the lighter deck motion, such that impact velocities are less than 2 ft/sec for the given sea state; and the specify a configuration of anti-sway tag lines such that the side load due to pendulation of the load is less than 2 percent of the related crane load.

Belsterling C.A., G.C. Gambs, and H.B. Hamill, "*Design Studies for a Stabilized Shipboard Crane,*" Franklin Research Center MA-RD-700-87031 (Sept 1987).

The Logistics-Over-The-Shore (LOTS) mission requires the capability to off-load containers and break-bulk cargo from large oceangoing ships onto a variety of lighters (and other small craft). Off-loading must be accomplished in all types of weather and in the presence of high sea states. Problems arise due to the motions of the vessels in inertial space and the motions of the vessels relative to each other. Existing shipboard cranes use a single cable with a cargo coupling mechanism (spreader) suspended from an overhead structure. Ship motion forces the cargo (or spreader) into pendulous action, allowing it to swing unchecked. Extreme difficulty is encountered when trying to mate the spreader with a container that is on the oceangoing vessel itself. Furthermore, depositing the swinging container on to a moving lighter without damage to cargo and hazards to personnel is even more difficult.

The Franklin Research Center has devised a means to stabilize suspended cargo in all six degrees of freedom (DOF), using six individually controlled cables in tension in a unique kinematic arrangement. These design studies establish the technical and economic feasibility of the new, stabilized cargo-handling system (Figure 2.1).

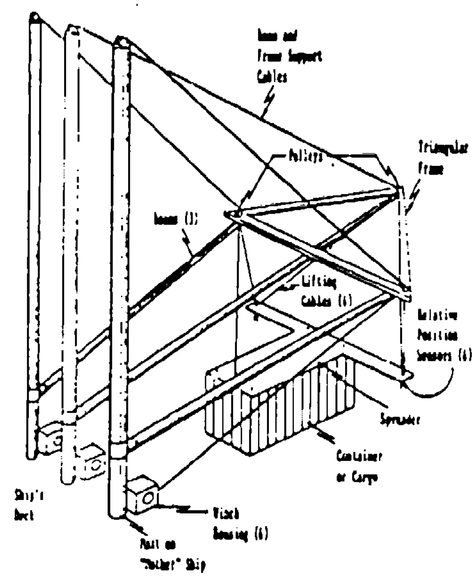

Figure 2.1 - The 6-DOF Stabilized Crane

Bird III, J. Dexter, Toni Ann Frizalone, and Charles F. Rushing, "*Platform Motion Compensator (PMC) Advanced Development Model,*" EG&G Washington Analytical Services Center, Inc. TR-W070-0001 (Jul 1983).

This report describes the development, fabrication, and testing of the Platform Motion Compensator (PMC) Advanced Development Model (Figure 2.2). The PMC makes offshore cargo handling possible by compensating for the sea-induced crane platform motions in conditions up to and including Sea State 3. PMC complements the pendulation compensation device, the Rider Block Tagline System (RBTS).

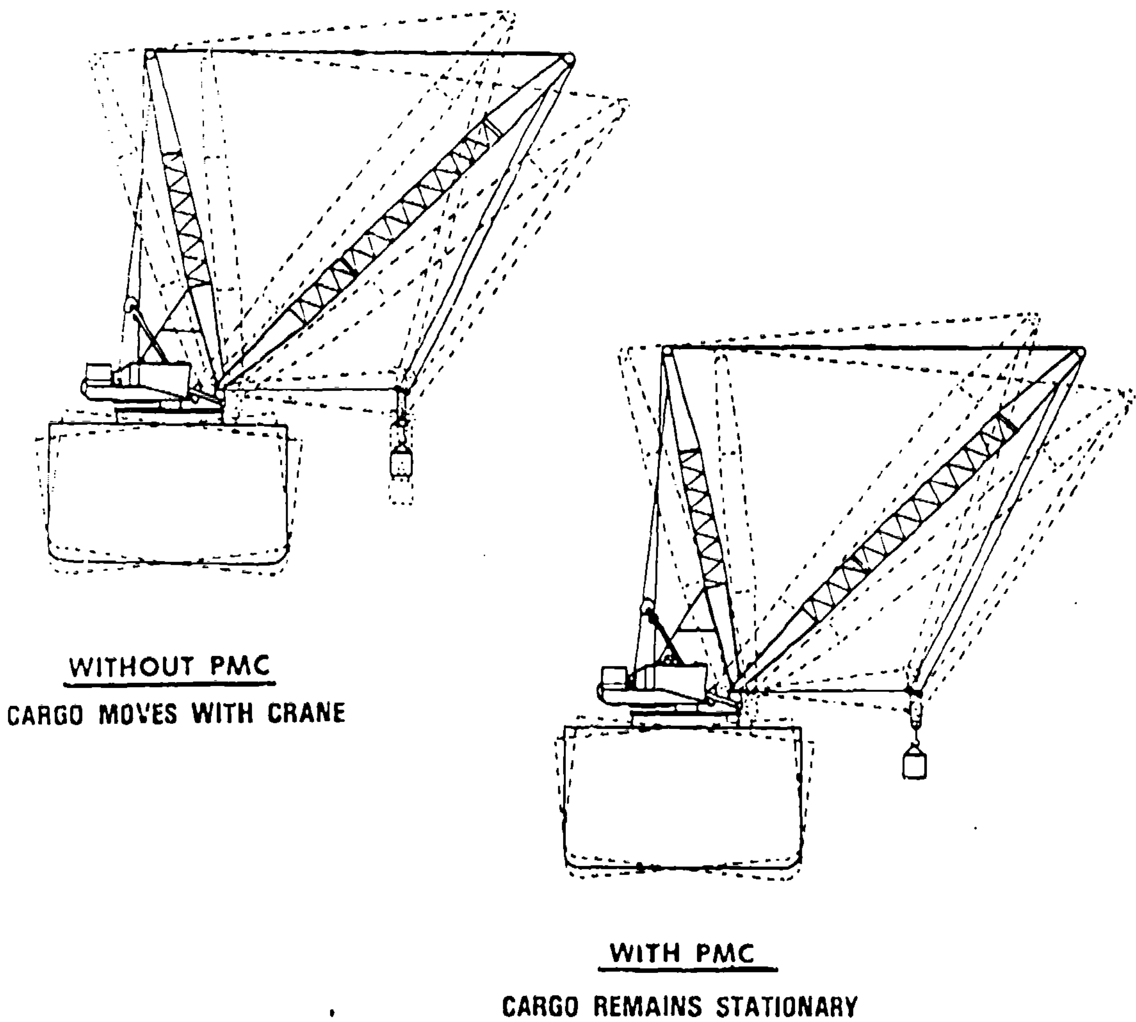

Figure 2.2 - The PMC Solution

Bird III, J. Dexter, Joseph A. Conte, and William B. Culpepper, "*Rider Block Tagline Electronic Control and Display System*," EG&G Washington Analytical Services Center, Inc. TR D960-0062 (Apr 1981).

The purpose of this report is to describe the design of the Rider Block Tagline Electronic Control and Display System, explain why certain changes were made from the original prototype design and show, through theory of operation, how it supports the other elements of the RBTS. The report includes a description of the system and its component hardware, a discussion of the electronic circuitry, manufacturers specification sheets and schematics of the electronic control system (Figure 2.3).

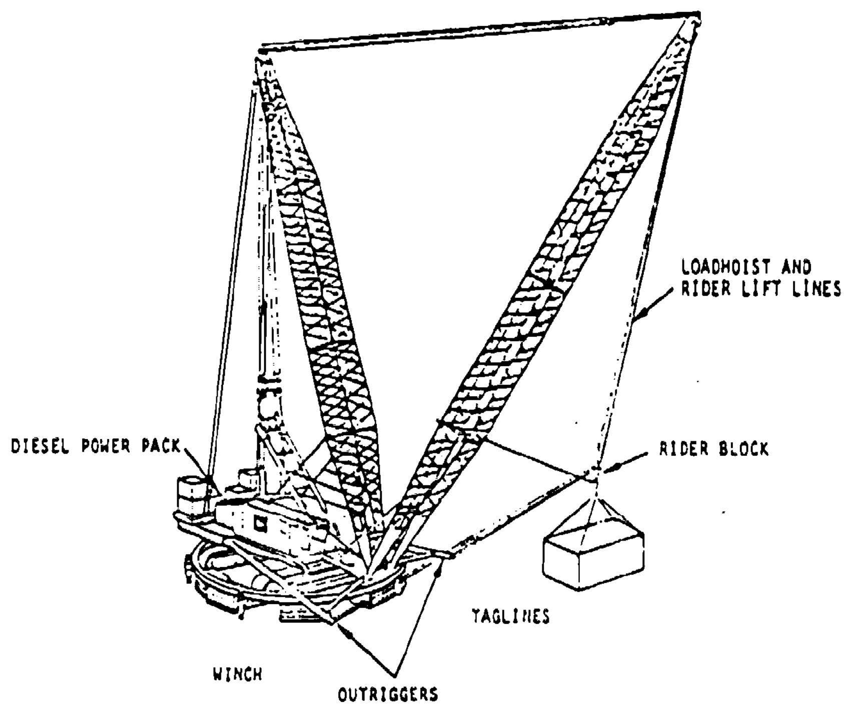

Figure 2.3 - Manitowoc 4100W Ringer Crane With RBTS

Bird, J. Dexter III, "*Motion Compensation for Offshore Container Handling,*" EG&G Washington Analytical Services Center, Inc. (Feb 1986).

This report presents the development and state-of-the-art of motion compensation technology for offshore container handling, particularly those developments that contributed to the success of the prototype motion compensation system installed on T-ACS 1, KEYSTONE STATE. A great deal of historical background has been presented to provide a better understanding of the work accomplished and to provide a firm foundation for future development efforts.

Several conclusions can be drawn from the efforts to date.

1) Motion compensation represents one of the most cost effective methods of providing high-volume, cargo offloading capability in elevated sea states.

2) The use of the Rider Block Tagline System (RBTS) is essential to control pendulation and provides safe and productive cargo transfer in elevated sea states.

3) The RBTS is readily adaptable to a variety of crane configurations, but required special attention to some human factors and design guidelines, outlined in Section II of this report, to assure a successful installation.

4) The Platform Motion Compensator (PMS), in conjunction with the RBTS, can provide container offload capability in Sea State 3 with significant crane ship motions when lighterage can be sheltered in the lee of the crane ship.

5) The Automatic Touchdown and Constant Tension concepts, demonstrated during JLOTS II, provide an effective and viable solution to the complex lighterage interface problem present in elevated sea states.

6) A motion compensation system, integrating the RBTS, PMC, Automatic Touchdown and Constant Tension systems, provides an effective means of meeting the T-ACS operational requirement of 260 containers per day in a Sea State 3 (Fig 2.4).

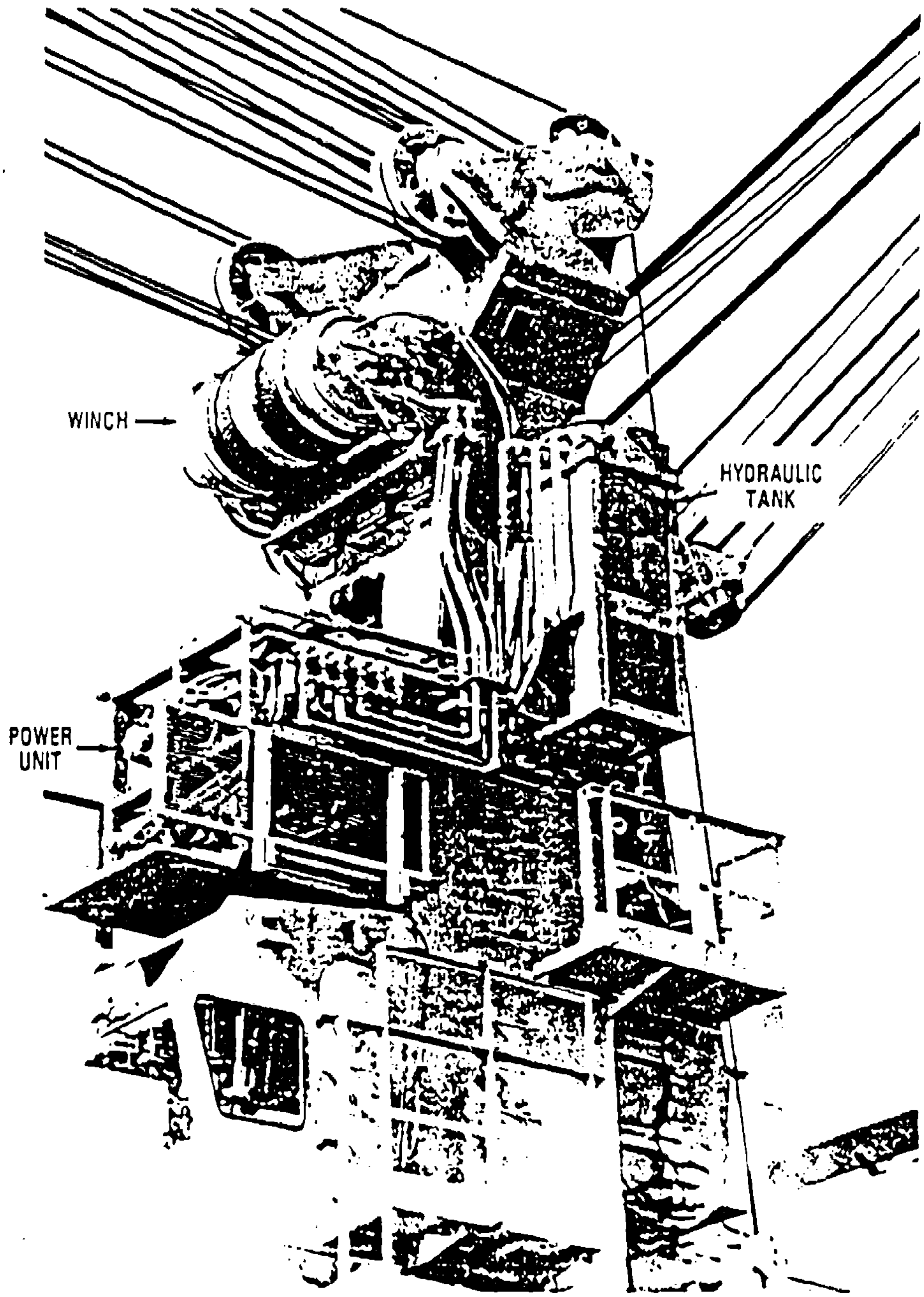

Figure 2.4 - T-ACS 1 PMC Installation - Power Unit, Hydraulic Tank, and Winch

Bird, J. Dexter III, "*A Methodology for the Evaluation of Alternative Offshore Container Discharge Systems,*" EG&G Washington Analytical Services Center Report TR-D200-0002 (1982).

A methodology has been developed for the evaluation of the cost and effectiveness of a complex system of dynamic elements driven by a single random input. This methodology was developed for the evaluation of amphibious material handling systems and applied to the Navy's Container Offloading and Transfer System (COTS). An example system configuration has been examined in detail in order to demonstrate the application of the methodology and the type of data needed to develop the necessary system relationships. A variety of applications were demonstrated, including determination of the effects of sea state and breakwaters and analysis of the tradeoff between breakwaters and motion compensating cranes. It was demonstrated that the methodology is easily adaptable to multidimensional optimization by the use of numerical techniques such as the steepest descent algorithm.

This methodology relies heavily upon Gaussian inputs, linearizable dynamic properties of the system elements, and a minimum of coupling between the dynamic elements. Future research should examine the possibility of handling non-Gaussian inputs, system dynamics that the not readily linearized, and systems where strong coupling exists between the dynamic elements.

In the particular case of the COTS problem, several areas warrant further investigations. More complex forms of motion compensating crane strategies should be examined, such as those that track the relative displacement between the cargo and the adjacent craft or optimal strategies that anticipate relative motion and land the cargo on the peaks where relative velocity is minimized, The interactions between the floating elements should be examined in greater detail. Particular attention should be given to the sheltering of one craft by another and the effects of secondary wave generation from the motions of the larger vessels. Finally, additional data needs to be collected in order to more accurately establish the component cost models and to verify or develop improved expressions for the container offload cycle times.

Bonde, L. and D. Dillon, "*A Concept for Improved Crane Performance In Offshore Operations*," EG&G Washington Analytical Services Center Report HCG TR 4694-0001 (Sep 1976).

The joint Army/Navy Marine Corps Off-Shore Discharge of Containership I and II (OSDOC I and II) Test/Evaluation exercises were conducted in 1970 and 1972, respectively, in order to explore through test and evaluation various techniques for unloading a containership moored offshore using full-scale equipment in a real environment. The primary difficulty encountered throughout the test was the inability to accurately place the container in the lighter. Two of the problem areas identified were the swinging of a container suspended from a crane operating on a ship or barge in a seaway and the potential for impacts of the container when the crane lowers it onto the deck of a lighter responding independently to the seaway.

This report summarizes various approaches and concepts for controlling container swing and impact caused by wave induced motion and examines the technical feasibility of two specific and promising methods: the rider block tag line system (RBTS) and shock absorbing spreader bar (SASB). From the results of this study, the RBTS and SASB are promising concepts for container control and impact attenuation when offloading at sea using a conventional revolving boom crane (Figures 2.5 and 2.6).

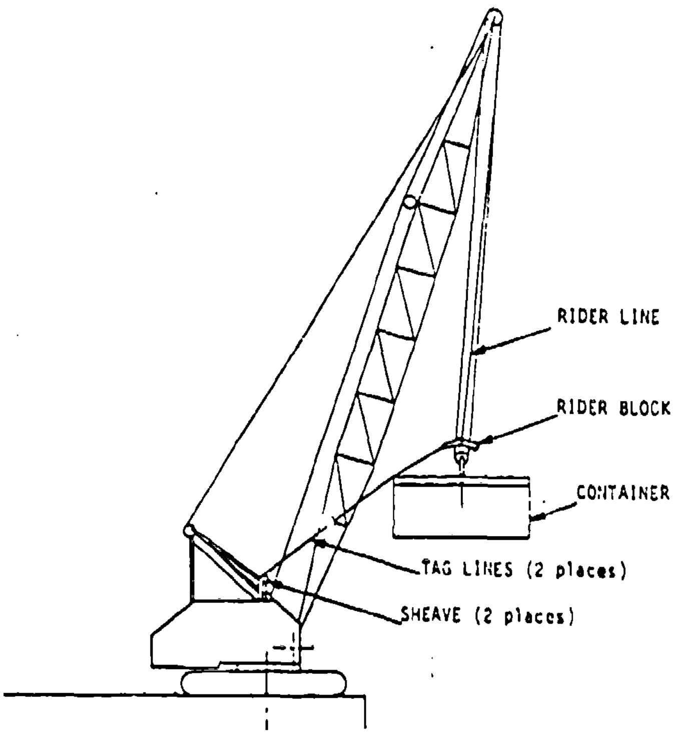

Figure 2.5 - Rider Block Tagline System (RBTS)

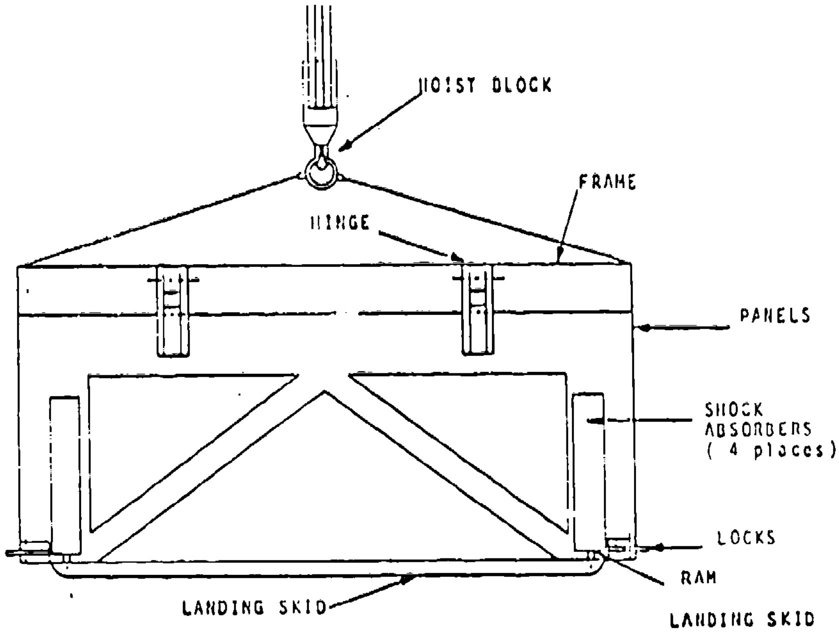

Figure 2.6 - Shock Absorbing Spreader Bar (SASB)

Browne, F. D., R. J. Casler, and S. W. Buck, "*Crane Control System Concept Formulation,*" The Charles Stark Draper Laboratory Report R-997 (Sep 1976).

An evaluation is made of two generic, crane-type, cargo handling devices for transferring heavy cargo in moderate sea states. Both modified conventional sea cranes and mechanical arms are considered in the study. The advantages and disadvantages of each type of device are outlined in a qualitative manner. Control system implementations and structural limitations are emphasized. With the limited analysis that has been performed thus far, the crane configurations have been rated, on a preliminary basis in terms of overall desirability for use as cargo transfer devices in Sea State 3 as follows: (1) conventional sea crane with auxiliary taglines, (2) conventional crane with hydraulic arm (Figure 2.7), (3) wireless hydraulic arm, and (4) hybrid hydraulic arm.

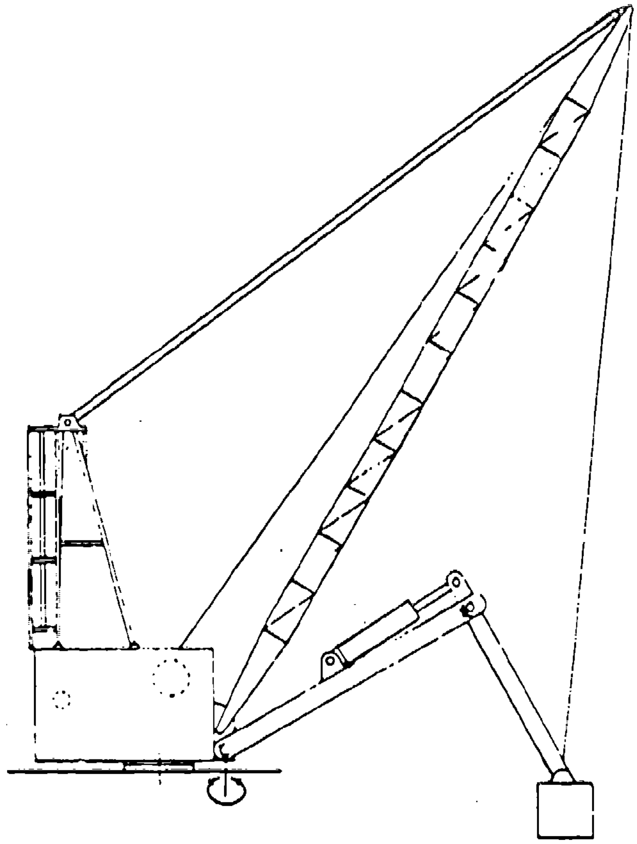

Figure 2.7 - Conventional Crane, Hydraulic Arm Configuration

Browne, R., R. Cassler, and E. Foster, "*Preliminary Control System Design for a Conventional Crane Cargo Transfer System Operating in Moderate Seas (Interim Report),*" The Charles Stark Draper Laboratory Report C-4724 (Sep 1976).

> The preliminary design of a control system that improves the cargo transfer capability of conventional cranes in moderate seas is presented. The control system consists of a tagline tension control system, to alleviate load swinging, and a semi-automatic "touchdown" control system. All aspects of the mechanical actuator design as well as the feedback systems design are presented. Numerical simulation of the control system dynamics is also discussed.

Charles Stark Draper Laboratory, Inc., "*Final Development Report For The Motion-Compensated Crane,*" Charles Stark Draper Laboratory Report R-1424 (Dec 1980).

This report addresses the design and testing of an Automatic Cargo Landing System (ACLS) based on the control technique presented in Section 1.4. Work began in April 1979, and the ACLS was completed and ready for shipment to the test site at the beginning of February 1980. Researchers spent two weeks testing the system at Port Hueneme, California, during February 1980. This report describes the ACLS design, the hardware and control algorithms, and the system tests. It also reports the test results and suggests improvements to the system based on those results.

Danish Hydraulic Institute, "*Investigations and Tests to Determine Hydrodynamic Forces and Moments on Ships Moored in a Current - Vol. ' -nd 2,*" Danish Hydraulic Institute Report CR 87.002 (Oct 1986).

Experiments with 1:50-scale models produced data on the horizontal force and the yawing moment exerted by a steady current on ships moored in shallow water. Data were obtained from one shop with various headings and for two ships arranged side by side in a beam current. The models were restrained by elastic lines simulating real moorings; for a single ship, rigid supports were also used. The experiments included brief investigations of the minimum flume width, turbulence, flow patterns, and flow-induced motions.

Davis, D.A. and J.J. Traffalis, "*OSDOC II Crane Platform Productivity as a Function of Sea State,*" NCEL Report TM-55-77-6 (July 1977).

A study was made of OSDOC II crane platform productivity as a function of sea state. The approach employed the CEL developed RELMO computer program fortified with engineering judgements based on field test data, OSDOC II experience and other available crane operational data as they applied.

Considering the approach used in this investigation and the restraints imposed by the paucity of the OSDOC II and post-OSDOC II field test data, the following findings and conclusions are justified: (1) The time for motion sensitive phases of container transfer, i.e., spreader bar into containership cell and MILVAN onto lighter well deck, increases with increased relative vertical motion between the crane boom tip and containership cell or lighter well deck; (2) Evidence form post-OSDOC II tests indicate that unskilled crews can be expected to 1.8 to 2.3 times longer to cycle containers under OSDOC type operations at sea depending, respectively, whether short boom or long boom cranes are used; (3) The crane onboard containership (COD) is the least affected by increased sea state conditions of the three CDF systems analyzed; (4) For the LST in quartering and beam seas, the dominant vertical component of motion between the crane boom tip and containership cell and between the crane boom tip and lighter well deck is the vertical roll component of the crane boom; (5) Sustained unloading productivity estimates indicate only slight differences in performance for the FDL and LST platforms when offloading a C5 Class containership; (6) Productivity of the FDL crane platform is slightly less when offloading the larger and more hydrodynamically stable C7 Class containership. This is due to the greater reach of the FDL crane when offloading the C5, resulting in an increase in the roll induced vertical component of crane boom tip motion (the dominant component of motion); and (7), Narrow-banded swell (having a sufficiently high energy content) with a dominant period around the natural roll period of any crane platform will seriously degrade - if not altogether prevent - cargo handling operations.

Davis, D. A. and H. S. Zwibel, "*The Motion of Floating Advanced Base Components in Shoal Water - A Comparison Between Theory and Field Test Data,*" NCEL Report N-1371 (Jan 1975).

As part of the Navy's program to develop mobile port facilities, an analytical model has been developed to compute the relative motion between vessels in regular and random seas. The model, which considers all six degrees of vessel motion, is based on strip theory and is suitable for analyzing all single hull linearly moored vessels. Ship motion and wave data obtained during recent offshore discharge of containership II (OSDOC II) field tests were used to validate the model. The results presented herein suggest that the model closely predicts the absolute motion of ocean going vessels (2,000 tons and larger), but that its predictions of lighter motions when the lighters are in close proximity to larger craft are less accurate. The probable cause of this disparity is hydrodynamic interaction, an effect which is not presently considered in the model.

Davis, D. A. and J. E. Kasunich, "*Static And Dynamic Stability of Crane Platforms,*" NCEL Report 55-75-07 (Mar 1975).

The unloading of deck-stacked or cell-stored containers into the receiving lighterage is perhaps the most critical phase in the cargo transfer operation. Wave induced motion can cause large crane boom displacements regardless of whether the crane used to unload containerized cargo is located on the containership or is operating from a floating platform moored alongside. Excessive motion of crane booms results in load pendulation, lack of control in container placement aboard lighters, and unacceptable levels of container and lighter damage due to load impact. It is this critical problem of crane platform motion which is the subject of this study.

Dobeck, Gerry J., "*Control System Analysis for COTS Crane-On-Deck Configuration,*" NCSC TR-360-81 (Jun 1981).

A feasibility study of using a modified commercial crane to transfer cargo between ships in a moderate seaway is presented. The critical choice of sea spectra for design and analysis is presented. Speed drag taglines and fixed length taglines are investigated for reducing horizontal load pendulation. Results are compiled in a nondimensional form for extrapolation to different load weights, loadline lengths, and seaway frequencies. Transferring cargo containers. Results of a complete nonlinear simulation are given showing all systems operating simultaneously.

Foley, Edward W., *"Relative Motion Measurement During Interface Operations Between the USS SPIEGEL GROVE (LSD-32) and the JEFF CRAFT,"* DTRC SPD-0943-02 (Oct 1980).

This report describes trials that were conducted onboard the USS SPIEGEL GROVE (LSD-32) involving the interfacing of the LSD-28 Class with the experimental amphibious assault landing craft designated the JEFF CRAFT. Currently, two configurations of the air cushion JEFF CRAFT are undergoing evaluation by the Navy. JEFF (A) was not in full readiness for the interface trials, and only participated in a limited fashion. JEFF (B) was the primary test vehicle which successfully negotiated entries and exits from the LSD well area with the LSD at anchor in protected waters and underway in the Gulf of Mexico. The interface trial effort involved many technology groups studying various aspects of the interface operations. The aspect of concern in this report is the relative motions between the LSD and the JEFF CRAFT as they came into close proximity. More specifically, this effort was to define the relative motions that might result in collision or impact between craft and ship. During the at sea evaluations, sea conditions remained very benign such that relative motions were limited to horizontal plane motions and no impacts or collisions were noted.

Goodyear Aerospace Corporation, *"Development of Energy Spectrum Techniques for Relative Motion Crane Horsepower,"* Goodyear Aerospace Corporation Report GER 16252 (Sep 1975).

After linearizing the expression for the horsepower requirements of Relative Motion Compensating Cranes, traditional methods of energy spectrum analysis are applied to the development of a calculation routine for estimating the horsepower of such cranes. A sample problem is presented for a Rotary Boom Type Crane with Articulated Arm. A brief study is conducted of a promising approach to the problem of non-linearities.

Goodyear Aerospace Corporation, "*Relative Motion Compensation Sensing System Study For Cargo Transfer in Rough Seas,*" Goodyear Aerospace Corporation Report GER 16191 (Dec 1974).

The effort described herein comprises the second phase of a program to provide a crane having relative motion compensation for the transfer of cargo in rough seas.

The effort on this program was directed exclusively to the relative motion sensing system and included establishing preliminary requirements and generating concepts to satisfy the requests. A trade study was then conducted to establish the baseline sensing system. This baseline sensing system is described in detail.

A development plan was then generated for the baseline sensing system which at its completion will prove feasibility of the sensor system (Figure 2.8).

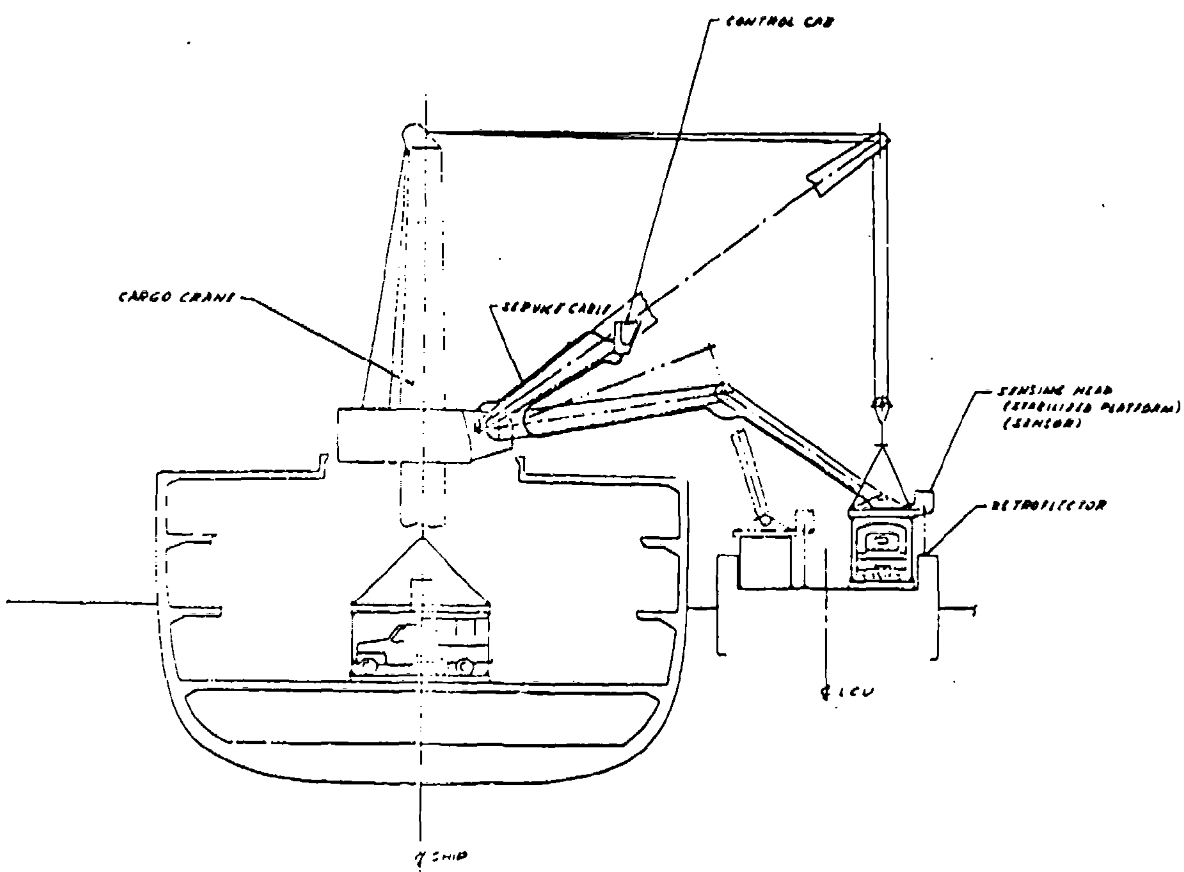

Figure 2.8 - Major Components of the Recommended Sensing System

Goodyear Aerospace Corporation, "*Relative Motion Compensation Study For Cargo Transfer In Rough Seas,*" Goodyear Aerospace Corporation Report GER 15872 (Feb 1973).

This study recommends a solution to the problem of the inability of existing cargo handling systems to off-load cargo during rough sea conditions in amphibious operations. An active crane system with relative motion sensing equipment that automatically causes the cargo to follow the deck of the lighter on which it is to be set. Motion compensation ability in transverse (surge and sway) and vertical (heave) directions is provided.

Specifically, the system recommended consists of a main boom and a king post configuration capable of handling 70 tons at a reach of 72 feet. An articulated arm is attached at the base of the main crane capable of providing pendulation control and relative motion compensation capability in any transverse direction.

Vertical motion compensation is provided by power applied to the main crane winch. Capacity of the crane system when used in a motion compensation mode is 50,000 pounds. At the heart of the system is a motion sensing device which provides a signal to the control mechanism which in turn automatically drives the package to follow the deck of the lighter. A secondary passive system of bumpers is recommended as an answer to the problem when the installation of an active crane system is not possible.

Goodyear Aerospace Corporation, "*Demonstration of a Relative Motion Sensing System for Cargo Transfer,*" Goodyear Aerospace Corporation Report GER 16418 (Dec 1976).

A program is described in this report for the development and laboratory simulation test of a breadboard model relative motion sensor incorporating a solid-state digital pattern tracker, a TV camera, and a vertical reference. The objective was to demonstrate the feasibility and evaluate the performance of the sensor for measuring relative motion between a crane-mounted sensor and a lighter. The sensed relative motion, both translation and rotation, could be used as an input to the crane's control system for automatic container motion control when loading or for retrograde during high sea states (Figure 2.9).

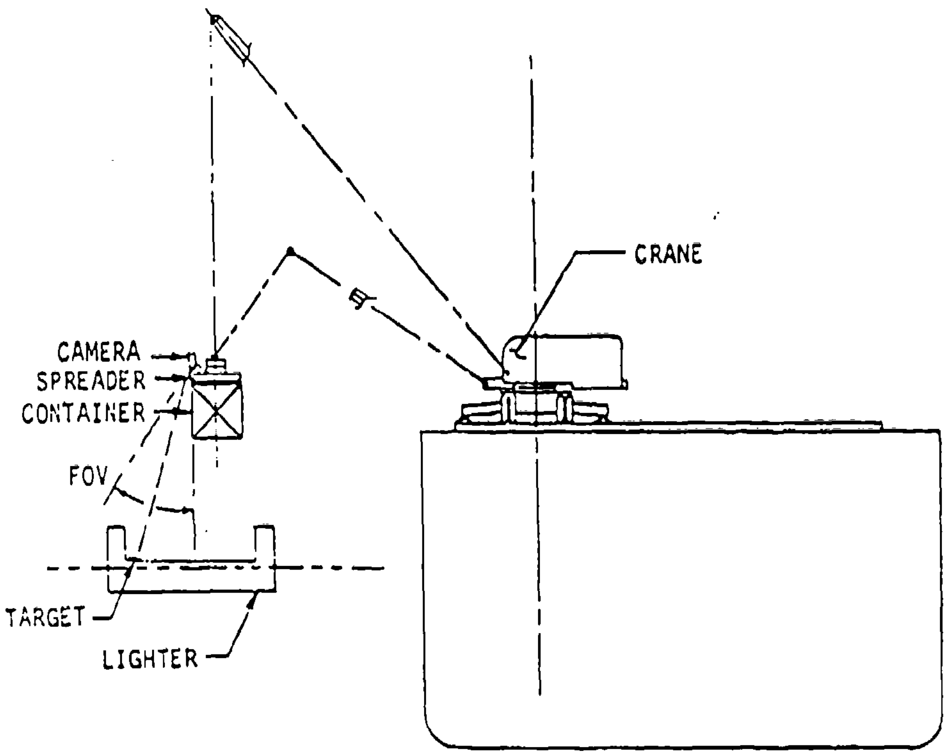

Figure 2.9 - Cargo Offloading

Kim, C.H. and M.C. Fang, "*Vertical Relative Motion Between Adjacent Platforms in Oblique Waves*," Journal of Energy Resources Technology, Vol. 107, pp. 455-460 (Dec 1985).

The paper presents a strip theory and its correlation with experiment and analysis on the relative motions of two ships. The ships are in close proximity and in parallel position in oblique waves. The two-dimensional procedure takes account of the hydrodynamic interaction between two cylindrical bodies. It was found that the strip method is a useful technique to predict the hydrodynamically coupled motions of two ships (Figure 2.10).

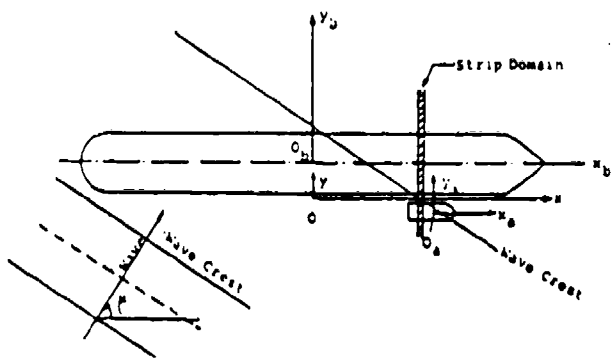

Figure 2.10 - Coordinate Systems and Plan View

Kim, C. H., "*Description of the Computer Program for Coupled Side by Side Ship Motion*," Stevens Institute of Technology (Jul 1985).

The computer program relative motion can calculate the vertical and lateral relative motions between the tip of a crane of a ship and an unloading deck area of a lighter adjacent ship in oblique seas.

Kwok, Lloyd, *"Model Study of Bottom Founded and Moored Semi-Submersible Loading/Offloading Terminal (Vol. I and II),"* Arctec Offshore Corporation MA-RD-840-88005 (May 1987).

In January and February of 1987 a 1:48 scale model study of a mobile offshore drilling unit (MODU) as a cargo handling in-situ port facility was conducted by Arctec Offshore Corporation (Figure 2.11). In this test program, the MODU considered was a semi-submersible of the GLOMAR Arctic Class. Two configurations were investigated. A bottom founded semi-submersible deployed as a container loading and offloading terminal was studied in the first configuration. In the second configuration two mooring systems, each with eight mooring lines, were considered for a floating semi-submersible. In this case the semi-submersible was used as a grain handling facility.

Conditions under Sea States 1, 3 and 5 were investigated when either the container or grain vessel was berthed alongside the semi-submersible. Sea State 7 was used to study the behavior of the semi-submersible alone in storm conditions. Modified Pierson-Moskowitz spectra were used to represent different sea states. Measurements were recorded on magnetic tape and oscillographic charts. High quality surface video recordings, as well as still photography also documented the tests. This report describes the models, test setup, test results and feasibility of the concept.

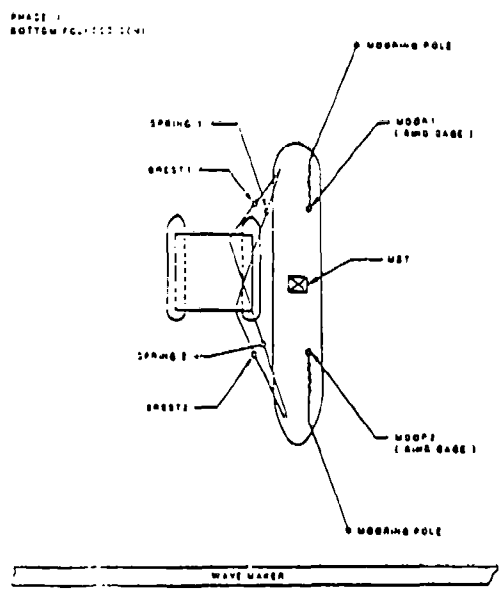

Figure 2.11 - Ship/Semi-Submersible Mooring Layout

Layne, Douglas E., "*The Interaction of Two Vessels in Close Proximity*" DTRC SPD-741-01 (Dec 1976).

Interaction effects examined in the NAVSHIPs sponsored study concerned the relative heading and rudder angles required when one ship is approaching, running alongside, and pulling away from another ship. These effects are obtainable by measuring forces and moments during captive model investigations. More specifically, the study concerned tow restrained models, one of which was positioned statically relative to the other. One model represented an aircraft carrier of the CVA-58 Class and the other, a fast combat support ship of the AOE-1 Class. The principal objective was to assess the interaction between these ships at various speeds and separations and thus determine the corresponding rudder and drift angles required to provide neutral forces and moments. Determination of drift angles has been neglected in earlier experimental work. It was included here because even though these values are thought to be relatively small, they could alter the amount of angle required of the rudder.

Netherlands Ship Model Basin, "*Results of the Tests with U.S. Navy SPM Fuel Buoy,*" Netherlands Ship Model Basin Report No. 03330-1-GT (Preliminary) (Jun 1979).

A series of wave tank test were conducted at the Netherlands Ship Model Basin to validate the design approach of the U.S. Navy's SPM fuel buoy. Maximum anchor leg and hawser loads were determined to be 634 kips and 541 kips, respectively. An anchor leg load of this magnitude meant that two 300K embedment anchors would be required for each leg, a total of eight anchors for the SPM installation. The test at the NSMB also indicated that excessive ship's roll would occur in a 4-knot perpendicular current if waves exceeded the lower end of Sea State 5 (significant wave height of 8.0 feet). This was true regardless of the size of the tanker tested (20,000 - 70,000 DWT).

Offshore Technology Corporation, "*Model Studies of a U.S. Navy SPM Fuel Buoy, Volume I,*" Offshore Technology Corporation Report No. OCT-78-16 (Nov 1978).

Early in the conceptual design phase of the SPM fuel buoy program, tests were conducted at the Offshore Technology Corporation to determine the maximum loads to be expected in the buoy anchor legs and tanker hawser for the design environmental conditions established by the Navy. Three classes of tankers were used in the tests: (a) 70,000 DWT, representing the maximum size tanker expected to moor at the buoy; (b) 20,000 DWT, a small storage and transfer tanker which would remain moored tot he buoy for an extended period; and (c), 40,000 DWT, a "most likely sized" tanker which would moor to the storage tankers in one of two modes: in tandem (astern) and alongside, separated from the storage tanker by large foam-filled marine fenders.

Results from this first series of tests for a 70,000 DWT tanker indicated that the maximum load to be expected in a buoy anchor leg was 465 kips. The maximum measured load in the hawser between the buoy and tanker was 417 kips. It was learned that mooring the 40,000 DWT product tanker to the storage tanker (storage tanker bow moored to the buoy) presented a number of problems. The most serious condition occurred when the tankers were moored abreast. Even relatively mild sea conditions were sufficient to cause excessive ship's roll, thus, seriously complicating the POL transfer operations.

Pope, W. S., J. M. Harris, A. M. Plummer, and D. Ensminger, "*Summary Report on Relative Motion Sensing Concept Review,*" Battelle Columbus Laboratories (Jun 1976).

The objective of this concept review program was to identify a preferred candidate system for sensing relative motion in 3 axis suitable for fabrication and evaluation in "breadboard" form in a subsequent program. Of the systems studied, two were selected for further development and two were proposed as back up or reserve systems in the event that unforseen difficulties precluded development of either of the two primary systems. For the primary systems, a multiple tag line is proposed to sense relative motion in the horizontal plane, and an accelerometer based system for sensing vertical relative motion. The backup or alternate systems are: an acoustic Doppler sensor and a single tag-line follower servo system, both for relative vertical motion.

Rossignal, Grant A., "*MS CYGNUS, SS AMERICAN TROJAN, and Causeway Platform Facility Relative Motion*," DTRC SPD-515-03 (Feb 1983).

This report presents the results of relative motion trials conducted in support of RO/RO ship interface operations. The extent to which relative motions impose limits on causeway platform facility (CPF) operations is evaluated. The CPF was operated stern-moored to the MS CYGNUS, side-moored to the SS AMERICAN TROJAN, and underway while in transit. Variations of the CPF configurations were also evaluated. The results of these trials show that ship/CPF relative motions should not impact interface operations for significant wave heights up to 2.2 feet (0.7 meters). Stern and side moorings were successfully conducted under fairly mild environmental conditions, with the stern mooring providing the greatest CPF sheltering from incident waves. Limitations of existing configurations did not permit CPF and causeway ferry (CWF) operations to be conducted for significant wave heights greater than 3 feet (0.9 meters). LCU/CWF to CPF relative motions will have greater impact on limiting future RO/RO ship interface operations than will ship/ramp/CPF relative motions.

Ruth, Lawrence C., "*An Investigation of the Absolute Lighter Motions Involved in the Container Offloading and Transfer System (COTS) Trials*," DTRC SPD-515-02 (Mar 1976).

Ship motion and wave measurements were conducted for various lighters participating in container offloading and transfer system (COTS) trials off Coronado Island, San Diego. Their purpose was to evaluate the effects of waves and lighter motions on the offloading and loading procedures. Motions of a warping tug causeway system, an LCM 8, and a LCU 1652 were measured while they were alongside a bumper system connected to an elevated causeway. All lighter motions were seen to be very small due to low seas predominant at the time of the trials.

Sankar, S. and J. Syoboda, "*Active Stabilization of a Ship Borne Crane,*" 51st Symposium on Shock and Vibrations, USA, Oct. 21-23, 1980: 237-247.

This paper presents the dynamic performance of an active-stabilizer for controlling a ship-borne crane under heavy weather. The governing equations are derived and solved using digital simulation. The mathematical model served as a basis for the dynamic design study of the crane system. The active-stabilizer for the crane uses a heavy compensating boom to decouple the submersible from the motion of the support ship. The motion compensation system uses an active servo-control system operating in parallel with a soft hydro-pneumatic spring. The crane boom maintains its position in respect to the shore by monitoring both the acceleration of the boom tip and the boom angular position. The active compensation system consisting of a linear hydraulic servo actuator coupled in parallel with a hydraulic accumulator allows for adjustment of the gas prechange pressure according to the load. The study indicated that the sizing of the actuator system and its adjustment capability significantly affects the energy requirements of the active damping servo actuator system.

Summey, D.C. and T.C. Watson, "*Ship Motion Trade-Off Analysis for the Container Offloading and Transfer System (COTS),*" NCSC Report TM-361-82 (Nov 1982).

Ship motion response amplitude operators (RAOS) were predicted for three containerships and three lighter vessels. Ship motions (surge, heave, sway, pitch, roll, and yaw) were also computed for three sea spectra: a Pierson-Moskowitz, a Bretschneider, and a Bretschneider plus swell. Ship and crane motion data for head, quartering, and beam wave incidence angles are presented in tabular form with plots comparing barge motion RAOS given as a function of wave incidence angles. Significant displacements, velocities, and accelerations were calculated in each of the three coordinate directions for various rigid boom crane configurations. A sample procedure is presented for using the large volume of motion data available for the container offloading and transfer system (COTS).

T.Y. Lin, International, "*Navy Floating Pier: Investigation of Dynamic Motions, Ramp Supports and Flexible Utility Connections,*" T.Y. Lin, International CR83.030 (June 1983).

The feasibility of a floating pier concept for Navy surface combatants has been investigated further by studying the dynamic motions of the pier and by producing preliminary designs of the ramp supports and flexible utility connections (Figure 2.12). The dynamic motions of the pier were analyzed for the loading cases of berthing impact of ships, waves generated by passing ships, waves created by storm conditions, long period seiche waves and ground motions from seismic events. For all realistic loading cases, the motions of the pier were reasonable and would not present problems to personnel or equipment operating on the pier. Practical designs have been produced for the ramp supports and flexible utility connections.

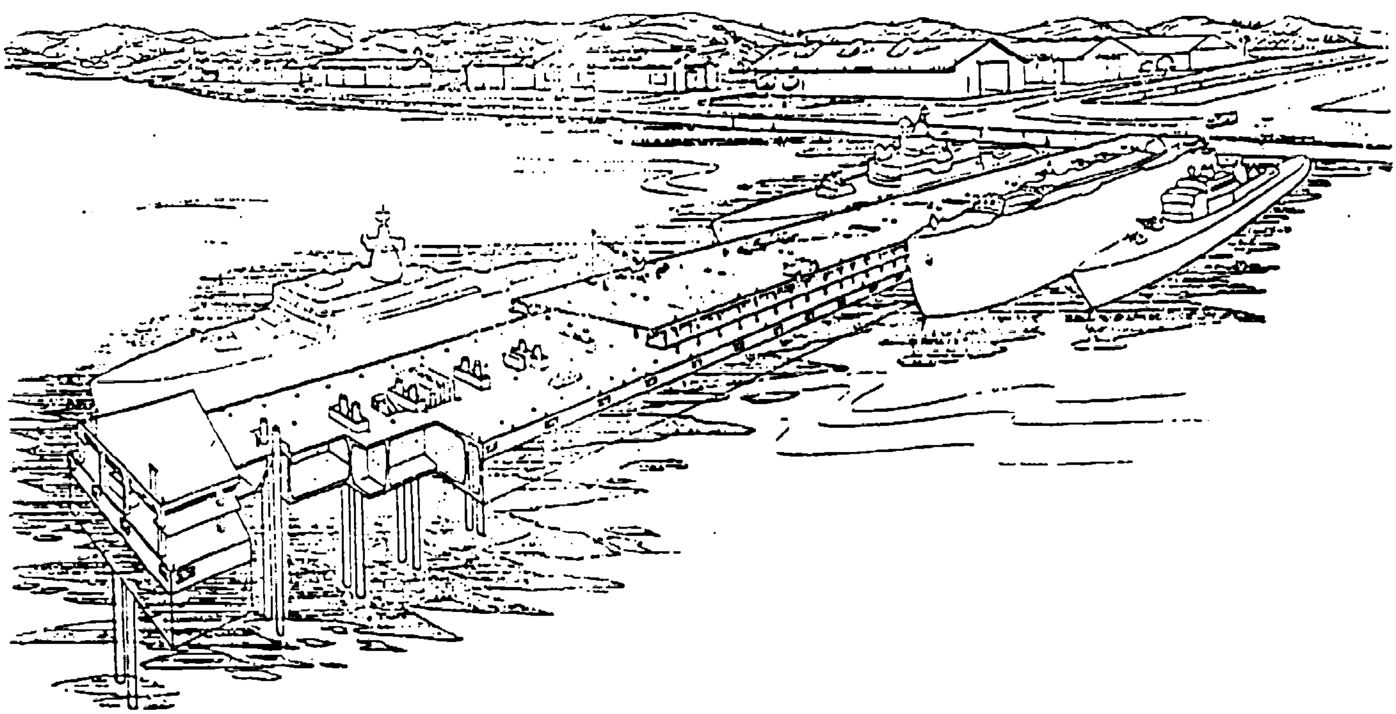

Figure 2.12 - Perspective View of a Navy Floating Pier

Ward, C. C. and F. R. Robinson, Jr., "*Dynamic Loads on a Shipboard Crane Boom Due to Ship Motion*," in: Offshore Technology Conference Proceedings, OTC Paper 783,321 (1978).

Motion of the ship produces dynamic loads in a ship-mounted crane boom. Nonlinear equations for determining these loads are developed using vector analysis and rotating coordinate frames. Once computed, the load functions are incorporated into the flexible boom matrix equation of motion. The elastic response of the boom to these time varying inertial loads can then be computed.

Welch, R.E. and F.J. Vyzral, "*Development of Ratings and Dynamic Simulation Procedures for Shipboard Mobile Cranes*," IIT Research Institute Report J6381 (Sept. 1976).

This report presents the results of the first phase of a research project which is related to the development of rating and dynamic structural analysis procedures for mobile construction cranes used in container offloading operations from cargo vessels. Objectives of the project are to develop, for shipboard mobile cranes: (1) simplified crane rating procedures which determine acceptable operating criteria and capacities both in general and for selected specific cranes; and (2) an analytical simulation of crane operations incorporating ship motions, crane dynamics and the effect of motion compensating systems on crane motions and forces based on a dynamic structural analysis procedure of the crane.

Wilson, V. Jeffery and William D. Briggs, "*Linked-Spar Motion-Compensated Lifting System*," PAT-APPL-006 825 (Jan 1979).

This invention relates generally to the handling of objects over the side of a ship at sea and, more particularly, to a deck handling system in which the motion of a surface support ship is isolated form a payload suspended in the ocean by a lifting cable.

Wolfe, M.J. and S.K. Wang, "*Impact and Operational Tests of the Container Hopper,*" NCEL Report N-1313 (Nov 1973).

The container hopper is designed to attenuate the swinging motions of a maritime van container suspended from a floating crane and then guide the container directly onto a truck trailer. It was developed under the auspices of the Marine Corps Development and Education Command and the Naval Facilities Engineering Command. There were two major phases in the development of the hopper. The first consisted of impact tests on one of the hopper shock absorbers. The second phase was a fully operation evaluation of the hopper during OSDOC II (Offshore Discharge Of Containership II) exercise in which a containership anchored 1 mile off the Virginia coast was unloaded with a floating crane. The crane lowered containers through the hopper onto flatbed semi-trailers, MILVAN chassis, and tandem rigs. Like the crane, the hopper and trucks were on a floating platform. Loading times as short as 1 minute were achieved.

Yumori, I. Roy, "*Impact of Ship Motion on At-Sea Cargo Transfer: Survey of At-Sea Cargo Transfer Analysis, Design, and Operation,*" NOSC TR 1020 (Mar 1985).

U.S. Navy, university, and private industry groups that have had experience in the analysis, design, or operation of at-sea cargo transfer equipment were contacted. A literature search was used to identify 48 related publications. A simple analysis was made to compare empirical design rules to analytical values. An examination of underway replenishment (UNREP) records was performed to evaluate the ability of current UNREP equipment to perform heavy-weather transfers.

The following are results from this study: (1) Past analysis of relative motions for over-the-side transfer did not include breakwater effect of the supply ship on the receiving lighter. This effect protects the lighter on the downwave side but increases motions on the upwave side. (2) Heavy-lift UNREP) cannot be performed in high sea states, under existing guidelines. (3) Existing empirical design rules for UNREP equipment are conservative and should be re-evaluated. (4) An experienced operator can make up for unsophisticated equipment. (5) Existing UNREP is being used in Sea States 4 to 6, but transfer rates of material are seriously degraded. (6) The bottleneck in the transfer of material does not lie in the UNREP equipment, but in the ability to clear the receiving area, especially with small ships. (7) Roll stabilization of the small combatant ships can improve transfer rates.

Zwibel, H.S. and D.A. Davis, "*A Treatment of a Non-Stationary Random Process - Load Transfer at Sea,*" NCEL (Oct 1972).

Many of the problems in shock and vibration are random in nature. The majority, representable as stationary stochastic processes, are analyzable by a variety of analytical techniques. There are, however, situations for which the process is non-stationary, e.g., transient phenomena, time variation of control parameters, etc. For these non-stationary processes, most of the analytic tools used for stationary processes are not applicable. In this paper, we treat a system that is non-stationary because of time varying parameters.

This non-stationary problem arises during off-shore cargo handling operations. A load is raised, shifted, and then lowered by a crane mounted on a floating platform. Horizontal boom motion (caused by wave-induced platform motion) forces the load line system to oscillate. Due to the raising and lowering of the load, the physical properties of this pendulum change with time. The magnitude of this induced oscillation for both random sea condition and swell is of interest. For swell, the system is not random; however, for a wind developed sea the system is stochastic due to the randomness of the forcing function. Both situations are discussed in this paper.

Zwibel, H.S. and D.A. Davis, "*Cargo Transfer at Sea - The Pendulation of Loads Suspended From Shipboard Cranes,*" NCEL Report TN N-1257 (Dec 1972).

A theory has been developed which could aid Navy materials handling specialists in their effort to evaluate load transfer systems for a modular port facility. The theory predicts the horizontal response of an unrestrained, wire suspended load in regular and random seas. The line length is allowed to vary with time, hence the resulting load response in random seas is characterized as a non-stationary random process.

The analysis is used to predict the motion of a load freely suspended from the boom of a Navy 100-ton floating crane. The results from the analysis and from the full scale tests at sea confirm in even moderate sea states. Taglines or other means of restraint will be required from inception through completion of each load transfer.

Zwibel, H. S., and D. A. Davis, "*The Relative Motion Between Ships in Random Head Seas (N-1183),*" NCEL Report N-1183 (Sep 1971).

As part of the Navy's program to develop mobile port facilities, an analytical model has been developed which can be used to compute the relative motion between vessels in regular and random head seas. The model, based on strip theory, is suitable for analyzing all single hull, linearly moored slender vessels. Since symmetry or moorings (if present) is assumed throughout, the motion is restricted to heave, surge, and pitch. Deep-water added mass and damping coefficients are used in the equations of motion, and the resulting model predictions are considered valid provided that the draft-to-mean depth ration does not greatly exceed 0.50. Typical results from the analysis are presented.

Zwibel, H. S., "*Motion of Freely Suspended Loads Due to Horizontal Ship Motion in Random Head Seas (N-1187),*" NCEL Report N-1187 (Oct 1971).

The theory is developed for the swinging motion induced in a wire suspended load due to the horizontal motion of a ship. An explicit formula is obtained for the significant amplitude of horizontal load motion when the ship is exposed to random head seas. Numerical results are presented for two typical cargo ships in a sea state three. It is found that very large motions are suffered by the load. For critical line lengths, resonance effects magnify the ship motion by several orders of magnitude. These results will be used to assist in the development of on-loading and off-loading devices for cargo vessels in open beach operations.

3.0 FLOATING VESSEL ALONGSIDE A FIXED PLATFORM

Arai, Shin-ichi, *"Effective Method for Reducing the Motion of Moored Floating Vessels,"* Hitachi Zosen Technical Review, Vol. 43, No. 4, pp. 220-227 (Dec 1982).

To reduce the slow drift oscillation of moored vessels due to winds and waves, a method was considered in which a sliding block on a sea-bed is connected by a spring with the moored vessel. It was anticipated that the Coulomb friction between the block and the sea-bed reduce the vessel motion. Experimental tests of an idealized model excited by sinusoidal forces were carried out. In addition, numerical simulations using the Runge-Kutta-Gill method, availability of which had been confirmed for the experiments, were carried out on an actual model excited by irregular wind forces. The following conclusions were obtained. (1) This method is highly effective in reducing vessel motion. (2) The reducing effect is influenced not by the mass of the block, but by the friction and the connecting spring. (3) There is an optimum ration of friction force to exciting force to minimize the vessel motion.

Arctec Offshore Corporation, *"A Study of Mobile Offshore Drilling Units Converted for Use As Temporary Unloading Facilities For Military Cargo,"* Arctec Offshore Corporation Report MA-RD 840-88003 (Sept 1988).

The Navy Strategic Sealift Program provides the ships and cargo handling systems to load, transport and offload equipment and material of U.S. military forces anywhere in the world. There exists a strong national requirement for military sealift capacity that will use existing commercial vessels in times of contingency or war. Unfortunately, recent trends in the maritime industry have developed vessels which are large and economical but which are highly dependent on shore support facilities for loading and unloading and thus less suited for military support use. Because of this, there is particular interest in developing innovative schemes for discharging and loading non-selfsustaining vessels in areas where access to shore-based handling gear may not be available. Fortunately, the U.S. has available a large number of vessels in its offshore exploration fleet which are fully capable of handling cargo at sea. Many of these vessels (mobile offshore drilling units - MODUs) are currently available due to the downturn in the offshore drilling industry and are likely to remain available for some time into the future (Figure 3.1). The purpose of this project was to examine ways of utilizing both jack-up and semi-submersible MODUs as Flexible Initial Response Shipping Terminals (F.I.R.S.T.)

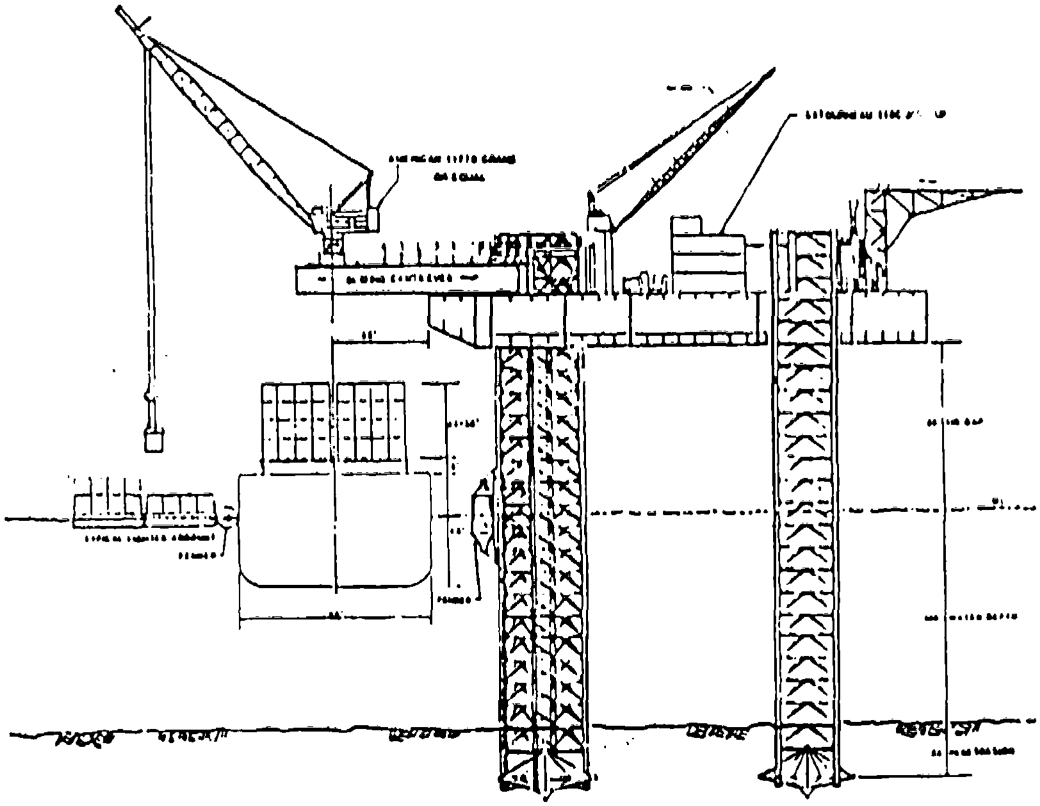

Figure 3.1 - Jack-up F.I.R.S.T.

Balfour, A.D. and D.G. Owen, "*Dynamic Behaviour of Platform Cranes,*" in: Offshore Technology Conference Proceedings, OTC Paper 803,794 (1980).

Mathematical models of varying complexity are developed to predict forces occurring in a typical offshore platform crane while lifting from a supply boat. Computer programs based upon these models are used to assess the usefulness of these simulations. It is shown that a simple two degrees of freedom model can be usefully employed at the feasibility design stage whereas a more sophisticated multi-degree of freedom model is required for detailed crane design. These programs are used to investigate the influence upon the induced loads of various operational parameters including the load lifted, the jib angle, the line speed and the instantaneous deck velocity. It is concluded that high dynamic loads will frequently arise in such cranes and that specifically written computer programs are necessary for effective derating or design. A statistical approach to the assessment of supply boat motions is used to show that maximum deck velocities can greatly exceed those predicted by the simpler methods previously used.

Clarkson, J.A. and F.M. Kenny, "*Offshore Crane Dynamics,*" in: Offshore Technology Conference Proceedings, OTC Paper 803,793 (1980).

The environment in which offshore cranes operate generate a number of factors which determine that the loadings on the structure are essentially dynamic in nature and not static as has been commonly used in design in the past. This paper presents the nonlinear equations of dynamic equilibrium and a method of solving these equations. From the theory developed a typical crane is analyzed and the general trends of behaviour are discussed.

Gernon, Bruce Joseph, "*Dynamic Response of a Tanker Moored to an Articulated Loading Platform,*" Ocean Engineering, Vol. 14, No. 6, pp. 489-512 (1987).

An analytical model was developed for the dynamics of an articulated loading platform in an operational condition, while remaining in a head seas position. The environmental excitation considered, resulting from groups of regular waves, included first- and second-order force contribution. The nylon hawser connecting the tanker to the ALP was modeled as a nonlinear spring. The hydrodynamic load on the tower was evaluated using Morison's equation, which was modified to account for the relative motion of the tower and the fluid particles. The hydrodynamic load on the tanker was calculated using linear diffraction theory based on the 2-D Helmholtz equation. The "near field" approach of Pinkster was used to evaluate the drift force.

Kray, Casimir J., "*Safety of Ships and Structures During Berthing and Mooring,*" Marine Technology Society Journal, Vol. 16, No. 1, pp. 29-38 (First Quarter 1982).

This report discussed berthing problems from the viewpoint of waterfront structure safety and reviews the available approaches to a determination of hydrodynamic mass. Recommendations are presented to decrease the degree and frequency of incidents of damage to fenders, ships, berthing structures, communication appurtenances, towers, loading implements and arms or other equipment.

Li, Yu Cheng, "*Action of Irregular Waves on Ships Moored on Terminals,*" Journal of Energy Resources and Technology Trans ASME, Vol. 104, No. 4, pp. 363-368 (Dec 1982).

For the analysis of the dynamic characteristics of ships moored at the offshore terminals under the action of wind waves, the moored ship system may be simplified to be linear. Introducing a transfer function the impact energy of a moored ship on the terminal resulting from a random sea may be obtained from the spectrum of the ocean waves. Furthermore, by using the directional function of impact the directional spectrum of the impact by ships can also be estimated. The results show that there is a significant relationship between the spectrum of the ocean waves and the impact energy of the ship.

Longreich, Randy and R.K. Wong, "*Supply Vessel Stern Mooring - A Passive System,*" 12th Annual Offshore Technology Conference Proceedings, Dallas, TX., May 5-8, 1980, pp. 195-204.

A Passive Stern Mooring System has been developed to allow supply boats and auxiliary vessels to remain in position adjacent to rigs and platforms during periods of inclement weather in order to facilitate the transfer of materials and supplies. The paper described the mooring arrangement and system operation, provides data pertaining to the elastic characteristics of double braided nylon rope and defines the procedures used to design each mooring system.

Moore, D.J., A.J. Watters, and I.S. McGill, "*Dynamics of Offshore Cranes,*" in: Offshore Technology Conference Proceedings, OTC Paper 803,792 (1980).

This paper describes studies of the dynamic behaviour of cranes used on fixed offshore installations. The studies encompass the development of an analog computer model, the validation of this model by comparison with measurements undertaken on an operating crane, and an assessment thereby of the limits of validity within which simple mass-spring models with few degrees of freedom can be applied to the derating of cranes.

Patel, M. H., D.T. Brown, and J.A. Witz, "*Operability Analysis for a Monohull Crane Vessel,*" Institute of Naval Architecture Supplemental Paper, pp. 103-113 (Jul 1987).

The use of a crane vessel for the installation of fixed structures in the North Sea is a crucial weather sensitive part of the development of an offshore oil field. This paper presents calculations leading to the definition of operability for a monohull crane vessel. ITM CHALLENGER, of 43,500 tons displacement which is presently under construction for ITM (Offshore) Ltd. Wave induced forces and moments acting on the vessel are used in conjunction with a mathematical model of the vessel, crane and lift wire elasticity and the pendulum swing of the hook load to deduce the coupled motions of the vessel and the hook load as well as to derive the magnitudes of vertical and lateral inertia forces on the crane jib. These results are used to derive a typical operability curve for the crane vessel. The potential Mathieu instability is also investigated and an envelope of conditions for stable motions is presented.

Sawaragi, Toru, Shin-ichi Aoki, and Masayoski Kubo, "*New Mooring System to Reduce Ship Motions and Berthing Energy,*" Coastal Engineering in Japan, Vol. 27, pp. 303-313 (Dec 1984).

In this paper, the improvement of mooring system in a harbor often attacked by storm waves is discussed by numerical simulation. First, it is pointed out that the ordinary mooring system which consists of fenders and mooring lines is not suitable for a ship moored to a quay from the viewpoint of ship motions and mooring forces. The inferiority of asymmetrical mooring and the effectiveness of the use of dash-pots are discussed. Then, the optimum mooring system in a harbor with respect to ship motions is proposed. These investigations are performed by numerical simulation for regular waves.

Stricker, P.A., "*Active/Passive Motion Compensating Crane for Handling a Remote Unmanned Work Station*," in: Offshore Technology Conference Proceedings, OTC Paper 783,236 (1978).

This paper describes the concept, analysis, design, and sea trials of an active/passive ten ton capacity motion compensating crane (Figure 3.2) for deploying a remote unmanned work system. The same concepts can be employed to make possible the handling of tethered loads, including ship to ship transfers, in high sea states without the risk of cable failure or excess payload pendulation. Motion compensation is achieved by driving the boom up and down, while the ship is heaving, such that the boom tip remains substantially stationary with respect to a fixed point on earth. The combination of active and passive boom control resulted in significant savings in power consumption over a purely active system while providing excellent motion compensation. The crane, mounted at the stern of a salvage tug, has a reach of 30 feet (9 m), a boom tip stroke of 24 feet (7.3 m), and can deploy the vehicle over the side or stern. A travelling saddle on the boom positively restrains the payload during deck handling operations while moving the load inboard or outboard. The cable storage reel accommodates over 23,000 feet (7000 m) of Kevlar-wound electromechanical cable, and the entire crane can be disassembled into modules for air transportability. Performance data is provided for a sea state four operation, based on computer simulation predictions.

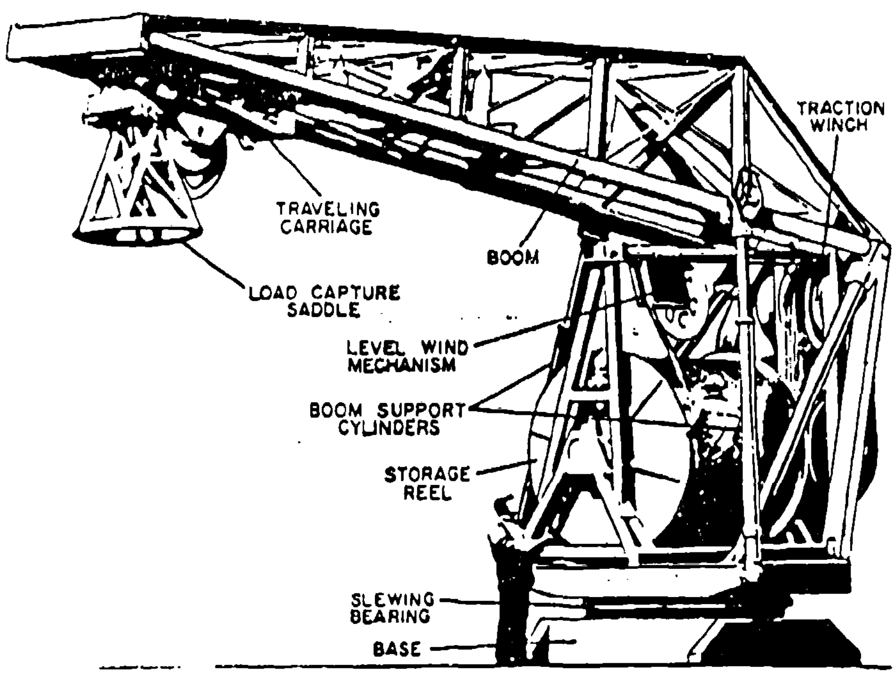

Figure 3.2 - Scale Model of the Motion Compensating Crane

van Oortmerssen, G., J.A. Pinkster, and H.J.J. van den Boom, "*Computer Simulation of Moored Ship Behavior,*" Waterway, Port, Coastal, and Ocean Engineering, Vol. 112, No. 2, pp. 296-308 (Mar 1986).

A model is described for the prediction of motions and mooring loads of ships and other floating structures moored in irregular waves, wind, and current. The mathematical model is based on the equations of motion in the time domain. This approach allows nonlinear and asymmetric mooring loads and arbitrarily in time varying excitation of the vessel. Input variables are: environmental conditions, mooring layout; elasticity characteristics of mooring lines and fenders; and geometry of the vessel. Output information includes: time histories, spectra and statistical values of motions, and mooring loads. Results are presented of an extensive validation study on the behavior of a 200,000 TDW tanker moored to an offshore jetty in shallow water.

4.0 RELATED TOPICS

Anon., "*Saga To Have Active LSIS Heave-Compensating System,*" Ocean Industry, pp. 59 (April/May 1990).

The light subsea intervention system (LSIS) is an active heave-compensated load handling system that has been selected to deploy the remotely operated maintenance vehicle (ROMV) being built for work at Saga Petroleum's Snorre field. A crucial point of LSIS is its ability to respond very quickly to vessel heave. The main LSIS components are an electronically controlled hydraulic system, several load cells and pressure gauges and a mathematical process model. Heave-motion data are generated by accelerometers aboard the vessel, allowing loads to be handled without a fixed external reference point.

The system is designed to operate from a moderate sized monohull vessel instead of a semi-submersible or a large monohull. Testing of the prototype took place on a 216-ft supply and anchor handling vessel. Wave movements of up to 6 m (20 ft) provided an environment for realistic trials. Residual load movements were mostly within the +/- 15 cm and never exceeded +/- 30 cm. Landing velocity of the load was 30 cm/sec.

Anon., "*Cargo Handling and Deck Machinery,*" Marine Engineering Log, Vol. 92, No. 2, pp. 35-42 (Feb 1987).

Drastic changes have taken place in the world's shipping industry in recent years - and will continue into the foreseeable future. Cargo handling and its related equipment both aboard ship and ashore must rank as one of the most revolutionary developments in the industry. While newer, improved designs in cranes, winches and similar equipment have appeared, computerization in operation of loading and unloading devices is the development that has opened up new territories for improvement in efficiency, speed and economy. Ship stability problems in the loading and unloading modes are now computer controlled, as is container handling equipment aboard and ashore - such as cranes and spreaders.

Anon., "*Guidelines for Supply Vessel Design,*" Naval Architecture, pp. 189-191 (Jul 1983).

This article offers some advice for those involved in the design and construction of modern multi-function supply vessels with a particular emphasis on afterthoughts. Three systems are presented which have been found to be most commonly fitted as an afterthought and which, in some cases, have caused problems with the arrangement of the vessel when at a late stage of construction.

Anon., "*Stabilizer and Anti-Heeling Tank Systems Combined,*" Naval Architect, No. 3, pp. 100-102 (May, 1979).

This article discussed a combined stabilizer and anti-heeling device in one tank system. This was developed to enable fast cargo handling, avoid damage to unlashed cargo at sea and improve the comfort of passengers and crew. It has now been extensively fitted on ro-ro vessels, ferries and container ships where side tanks can be provided, the space between them being available for cargo. The system is based on an athwartships U-shaped tank half-filled with water which is controlled to reduce the roll motion of the vessel at sea and the heel during loading and discharging. Side tanks contain the water and are connected by a water cross duct which is normally passed through the double bottom. Air exchange between tanks can either be through the atmosphere of the cargo holds or through another athwartships cross duct. One arrangement that has proved advantageous is to place the engine control room between the side tanks with the water cross duct running underneath. In large ro-ro vessels, the tanks can be arranged several decks higher with the cross ducts in the transverse beams.

Anon., "*New Crane Boasts Many Advantages,*" Marine Engineering Log, Vol. 78, No. 11 Oct, pp. 45, 114 (1973).

The newly developed and patented design, which the Cushing firm terms the ECONCRANE, was specifically adapted to Delta's LASH vessels, and boasts many important advantages over conventional shipmounted cranes. A significant weight reduction and a lower center of gravity have been realized by the elimination of jibs for outreach, and by the use of a single, transverse box girder supported by only two legs and truck-mounted sills. The crane also can handle any size container or oversized load, and could easily be married to another similar type of crane to handle large, heavy, or awkward loads. All components and systems have been designed with simplicity of operation, high component reliability, and ease of service and maintenance as design parameters of prime importance.

Anon., "*Fishing Pole Concept Seen as Lifesaver,*" Offshore, Vol. 45, pp. 176 (May 1985).

A contingent of Canadian companies and associations are completing field tests of a unique rescue system designed to eliminate the potential disasters inherent in normal lifeboat launchings during bad weather. The relatively simple concept includes an 80-ft flexible fiberglass boom held by a saddle support and hinge that are mounted on the rig at the evacuation stations. In its normal position, the boom rests at an elevated 45° angle. At the tip of the boom a wire cable or tagline, which is the same length as the boom, is connected to the bow of the lifeboat. As the lifeboat is lowered vertically towards the water by its regular launch cables, horizontal tension is transferred to the lifeboat by the tagline and boom causing the vessel to lower diagonally down and away from the rig (Figure 4.1).

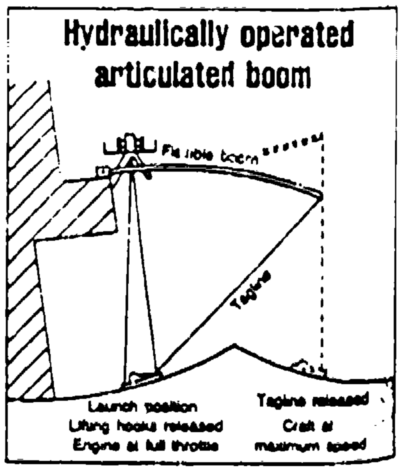

Figure 4.1 - Hydraulically Operated Articulated Boom

Bennett, D.A., "*Ships' Roll Stabilizers,*" Holland Shipbuilding, Vol. 29, No. 8, pp. 57-60 (Oct 1980).

This article reviews ship roll dynamics and response analysis. Stabilization techniques are reviewed. Equipment necessary to achieve stabilization is discussed.

Chalmers, H. and R. Sanders, "*Motion Compensation Deck Handling System for the Remote Unmanned Work System,*" ASME Paper, No. 80-WA/OCE-11, Nov 16-21, 1980, pp. 14.

The paper provides a detailed description of the Motion Compensation Deck Handling System of the Remote Unmanned Work System. It cites goals, described its special features, and discussed the major problems encountered and lessons learned during its checkout and ocean testing.

Davis, D.A., "*Static and Dynamic Stability of Navy Lightered (NL) Pontoon Causeways,*" NCEL Report TM 55-77-4 (June 1977).

A study was made of the static and dynamic stability of single-section and three-section end-linked Navy Lightered (NL) pontoon causeways which are an important class of lighterage in the Navy's advanced base logistics program. Roll, the critical component of causeway motion, was computed for various conditions of deck loading. In all cases studies, waves were assumed to be incident beam-on to the causeways. Graphs, specifying maximum loads which can be safely carried in given states of sea, are presented. These graphs should aid planners of causeway lighterage operations.

Drelicharz, Joseph A., "*Hydrodynamic Response of AMMI Causeway in the Surf Zone - VLAP,*" NCEL Report TN-1052 (Jan 1970).

Dynamic response of a light-weight, highly buoyant system can also produce critical problems in operations where relative motions between pontoon pier and ship, and pontoon barge and ship can be anticipated. Since a possibility of damage is inherent in such systems and because the tendency for future systems is toward lightweight materials and construction, pilot tests should be made to determine the dynamic response characteristics of pontoon systems. Such a study has been concluded at NCEL, modeling the lightweight AMMI pontoons; its description and results are presented in this paper. The study is limited in scope and application and, therefore, further studies with other pontoon systems are necessary before the results can be used in developing an analytical response solution for general operating conditions.

Fairlie-Clarke, A.C., "*Anti-Roll Devices: Active and Passive,*" Marine Engineering Review pp. 20-22 (Jun 1980).

Of the various types of stabilizer now available, those employing active fins are the most effective in general use. Their control systems achieve optimum roll reduction and the use of microprocessors and inertial sensors will make them increasingly sophisticated. This article discusses active and passive stabilization devices.

Hallanger, L.W. and R.L. Brackett, "*Development and Evaluation of a Motion Compensating Lift System for Deep Ocean Construction,*" NCEL Report R-829 (Dec 1975).

A system to raise and lower loads in the deep ocean while providing lift-line tension control and payload motion control was designed, fabricated, and tested. Design parameters included a maximum wet payload weight of 40,000 lbs at a maximum operating depth of 6,000 ft through Sea State 4 conditions when the system is mounted on a Auxiliary Recovery Ship (ARS) type vessel. A load-handling system of this type allows soft landing of a payload on the seafloor. In addition, the reduction in the dynamic tensions in the lift line allows the use of smaller lines for a given payload weight, greater payload capacity for a specified line size, or a greater depth capability for a given line size. The concept selected for development, called a "boom bobber", incorporated a boom pivoted end and supported by a relatively soft passive fluid spring. This spring decouples the payload from the motion of the support platform. At-sea testing included, determination of system performance for two payloads of 12,000 and 40,000 lbs wet weight. Cable tensions and time correlated motions of the ship, lift system, and payload were recorded. Data obtained were sufficient to prove the promise of the basic concept, even through both at-sea series ended with specific component failures.

Holmes, P., "*The Motions of a Moored Platform Due to Impulsively Generated Water Waves,*" NCEL Report R-683 (March 1965).

The unit impulse response function derived theoretically from the frequency response operator of a moored model platform 5 ft long, 8 in wide and 6 in deep is used to predict the model motions in heave due to particular trains of impulsively generated waves with typical wave lengths of 3 to 5 in water 2.5 ft deep. Experiments carried out in the NCEL wave basin are described, and a comparison is made between analytically predicted motions and those measured. It is found that the agreement is fairly good, and it is concluded that with improved accuracy in the determination of the frequency response operator, the technique may readily be applied in the determination of the response of a floating vessel to impulsively generated water waves.

Huang, T.S., "*Causeway Ferry Motion in Irregular Seaways,*" NCEL Report TN N-1715 (Nov 1984).

The causeway ferry is used to transport offloaded cargo from a ship via a causeway platform facility to the shore. The operation of the causeway ferry depends on its performance in irregular seaways. This effort evaluated and modified an analytical model for predicting causeway ferry motion responses. Model tests of a four-section causeway ferry were conducted to verify the applicability of the theory. The results suggest that the theory predicts motion response functions with acceptable accuracy. The practical application of the theory shows a 90 percent probability of maintaining a dry deck while operating in a sea state 3. Further investigations show a 98 percent probability of a dry deck while operating in a sea state 2.

Kirstein, Herwig, "*Active Heave Compensation Systems on Board of Vessels and Offshore Rigs,*" Marine Technology, pp. 59-61 (May 1986).

Active heave compensation systems are being installed in increasing numbers on ships and offshore platforms. In order to avoid installing excess power to cope with high peak requirements, a new hydraulic system has been developed by which energy is recovered during pay-out of the load. Systems with power matching control as described have a high degree of efficiency and therefore represent a step towards the future.

Koelbel, Joseph G, Jr., Nathan R. Fuller, Jr., Donald W. Handley, "*Paravane Roll Stabilization,*" 4th Ship Technology and Research Symposium and Proceedings, held in Conjunction with the SNAME Spring Meeting, Houston, TX Apr. 25-28, 1979, pp. 313-336.

The United States Navy is developing new vessels which will spend a large percentage of their time at low or zero speed and ship stabilization is required to permit the crew to function effectively. Paravane stabilizers are an inexpensive and effective method for low speed ship stabilization. The first use of the methodology to design an experimental rig for a 170 ton vessel is given.

Leendertse, J.J., *"Analysis of Critical Motions of a Floating Platform,"* NCEL Report R-187 (August 1962).

Theoretical calculations and experimental measurements were made to determine the response to heave in the significant frequency range of 3 to 4 sec of the CUSS 1, an ocean-bottom drilling barge to be used in experimental trials prior to project Mohole. Roll was measured also.

Approximately 20 min of pertinent barge motion measurements were made during two cruises while the barge drifted in the Santa Barbara (California) channel. No measurements of water-level variation (Sea State) were made.

It was found that in seas in the channel, estimated as from 2 to 3 ft in height and with significant periods of 3 to 5 sec as generated by winds of about 20 knots, the roll of the barge did not exceed three degrees and that its average heave at periods of 3 to 4 sec was about 1/4 in. The spectral density of the heave at a period of 3.4 sec was about 1/8 sq in/rad/sec.

Matsumoto, N., K. Suemitsu, M. Mzitsu, R. Fujimoto, and T. Kitani, *"Design Method for Characteristics of Dynamic Positioning System Equipped on Floating Offshore Structures,"* Nippon Kokan Tech Rep Overseas, Vol. 44, pp. 103-111 (Aug 1985).

A method of prediction of positioning motion was proposed for the purpose of basic design of a dynamic positioning system (DPS) equipped on a floating offshore structure. Then, comparing the results of tests made on an actual semi-submersible drilling rig with the predicted results by the proposed method, the applicability of the method was verified in regard to the transfer characteristics of motion in the horizontal plane for periodic thruster operation. In addition, with the most severe environmental condition for design assumed on this type of rig, a thruster capacity offering the required positioning characteristics was determined and then the status and dynamic holding capability was calculated. It was thus confirmed that the proposed method is useful for basic design of DPS equipped on a floating offshore structure.

McCarel, S., "*Advanced Cargo Transfer Facility (ACTF) Jack-UP Foundation Development,*" NCEL Report N-1791 (Dec 1988).

The jack-up foundation, used widely in the offshore industry, is being considered as foundation support for the Advanced Cargo Transfer Facility (ACTF). This foundation replaces the pile foundation currently used by the Naval Beach Group on its elevated causeway system (ELCAS). The basic jack-up foundation module discussed in this report consists of four support legs and provides discrete support points for several 200-foot-spanning structures which make up a 2,500-foot ACTF. While jack-up technology has been widely used, several developments were required to transport the modules by LASH vessels as well as to reduce the manpower requirements for installing an ACTF. The 120-foot long support legs for each module were reduced to 30-foot sections and stored within the module. During deployment of the module, a newly developed leg handling mechanism located on board each module, erects each support leg by joining the sections. The mechanism has automatic features that can assemble each support leg using a minimum of three men. Fabrication drawings for producing the leg handling of three men. Fabrication drawings for producing the leg handling mechanism are included in this report; however, no hardware has been fabricated or demonstrated to date. In order to meet the objectives of the ACTF, issues recommended for further study ACTF are module roll reduction and placement of the module in the surf zone.

McKechnie, R.E. and P.A. Stricker, "*Analysis of Active-Passive Motion Compensation Systems for Marine Towing Applications,*" ASME paper, No. 75-WA/OCE-13 for Meeting Nov 30-Dec 4, 1975, pp. 7.

This paper discusses the design of active-passive motion compensation systems for marine towing applications, with particular emphasis on the analysis involved. With the ship's response to ocean waves as the input, equations were developed or presented to predict the response of the compensator as a function of the various mechanical and control parameters. It is shown how the compensator response can be used as an index of performance for design purposes, or how, if desired, the motion of the towed body can be predicted from the compensator response.

Patel, Minoo H, "*Reducing the Wave Induced Motions of Offshore Vessels,*" Marine Engineering Review, pp. 22-23 (April 1986).

Excessive wave-induced motions can prevent semi-submersible or monohulled offshore vessels from carrying out production duties. However, a new motion suppression system has been developed to reduce these motions significantly and ensure maximum stability.

Penney, P.W., "*Offshore Vehicle Design: A Review of the Craft, Their Tasks and Equipment,*" Trans North East Coast Institute of Engineers Shipbuilding, Vol. 98, pp. 109-122 (1982).

Some topics discussed are these: offshore work tasks by a variety of vessels; the size of the offshore fleet; the offshore environment; the impact of work tasks upon vessels; major items of shipboard equipment; monohulls and semi-submersibles; drilling rigs; service craft; and new developments.

Ross, Jonathan M., "*Flopper Stoppers in Ocean Research,*" Journal of Naval Engineers, Vol. 92, No. 1, pp. 45-50 (Feb 1980).

"Flopper Stoppers" compose a simple passive system for decreasing the rolling of a ship dead in the water at sea. In this paper, expressions are developed that may be used for designing "Flopper Stoppers." One expression gives the decrement in roll angle caused by the "Flopper Stoppers." Other expressions give stresses on the suspension system and the ship by the damper plates.

Silveria, W.A. and C.S. Skees, "*Applications of Spectral Techniques to Forecasting Wave Conditions and Wave-Induced Vessel Motions,*" in: Offshore Technology Conference Proceedings, OTC Paper 783,280 (1978).

A spectral forecasting system has been developed to support at-sea operations of the offshore industry. At the heart of the system are spectral ocean wave models of the North Sea, the U.S. East Coast and Gulf of Alaska. The outputs of these wave models are combined with dynamical characteristics of operating vessels to produce predictions of wave-induced vessel motions. These predictions are provided on a real-time basis to offshore operators and contain information necessary to the operators' decision-making process. This type of information has been unavailable heretofore in the forecast mode. The system has been run operationally since mid-1976, and research and development actively continues on upgrading the system and extending its engineering applications.

Takezawa, S., T. Hirayama, C. Kazuyuki-Morooka, "*Practical Calculation Method of a Moored Semi-Submersible Rig Motion in Waves, (On the Effects of Moored Water Depth and Mooring Systems),*" Naval Architecture and Ocean Engineering, Vol. 23, pp. 67-82 (1985).

This paper is concerned with comparison between experimental results and a new practical calculation method proposed here for moored semi-submersible rig motion in waves, and good results were obtained. Mainly, this research deals with the study of the effect of the water depth and the mooring system on the semi-submersible rig motion in waves with wide frequency range. Three model scales were chosen for the experiment. And the use of a very small model of 1/ 300 scale as made it possible to obtain the response of the rig motion in a wide range of wave frequency which includes the roll and pitch natural periods at a very low frequency. Furthermore, such a small model experiment was realized by the newly developed remote measurement system based on the opto-electric device.

Turner, C.R., "*Zero Speed Seakeeping Characteristics of a Causeway Ferry Consisting of Four Pontoons Connected End-To-End,*" DTNSRDC/SPD Report 1075-01 (June 1983).

Seakeeping experiments were conducted to evaluate the performance of a causeway ferry consisting of four pontoons connected end-to-end which would be used to transport cargo from a floating platform to the beach during container-ship off-loading in support of assault operations where no port facilities exist. The aft pontoon contains propulsion units to drive the ferry with the forward three pontoons being assembled from standard watertight cans. Heave, roll, and pitch of the aft pontoon, heave of the forward pontoon, and the relative angular displacements between individual sections were measured in random and regular waves at zero speed for unloaded and loaded conditions. A spectral analysis of the random wave data was performed to yield transfer functions for comparison with transfer functions obtained from the regular wave runs. Values of significant double amplitudes from the random wave runs are also reported. In general, transfer function and significant double amplitude results for the two displacements are not greatly different, although in the loaded condition, the causeway ferry did experience considerable deck wetness for headings be- tween beam and bow quartering. Performance improved as heading angle increased and was best in head seas.

Weintraub, S.P. and P.M. Dodderage, "*A Review of Shipboard Cargo Handling Systems for Future Application to New Generation Amphibious Ships,*" EG&G Washington Analytical Services Center, Incorporated Report D620-002 (Nov 1980).

This report contains the results of an investigation into contemporary commercial shipboard cargo handling and its applicability to proposed amphibious Naval vessels, based on assured mission parameters. Most significant in the commercial world has been the change in dunnage and packaging cargo, plus the advent of multipurpose ships with a capability to handle floatable, heavy-lift, and roadable cargo with emphasis on rapid turn-around time. In naval amphibious ships, the IVAN ROGOV of the USSR with its floodable well aft and loading ramp forward is most innovative. Direct comparisons between commercial ships and Naval ships must be made with caution since operational requirements differ; however, such comparisons are useful since there are more similarities between a multipurpose heavy lift commercial ship with roll-on/roll-off (RO/RO), float-on/float-off (Flo/Flo), and lift-on/lift-off (LO/LO) capabilities to a Navy amphibious ship than there are between a commercial pallet-handling warehouse concept and an LHA.

Witz, J.A. and M.H. Patel, "*Control of Marine Vehicles with Pneumatic Compliances,*" Engineering Structures, Vol. 9, No. 2, pp. 124-133 (Apr 1987).

This paper is concerned with the use of pneumatic compliances to control the heave, roll and pitch motions of marine vehicles when disturbed by operational loads. The pneumatic compliances are in the form of open bottom air tanks attached to the vessel at the water line and extending above and below still water level. Each tank traps a volume of air above its internal water level. Active operation of these tanks involved controlling the amount of air trapped within the tanks. Three application studies are presented which involve suppression of motion due to vessel loading and crane operation on semisubmersible and monohull vessels.

5.0 ADDITONAL BIBLIOGRAPHY OF RELATIVE MOTION COMPENSATION FOR CARGO HANDLING OPERATIONS

Abkowitz, M. A., "*Relative Motion Between LCU and Mariner Models in a Seaway (Addendum),*" MIT Report (Mar 1977).

Abkowitz, M. A., "*Relative Motion Between LCU and Mariner Models in a Seaway,*" MIT Report (Oct 1976).

American Petroleum Institute, "*Offshore Cranes, API Specification 2C,*" 2nd Edition, (Feb 1972).

Anon., "*Kran med Bolgevelses-Kompensator,*" Teknisk Ukeblad/Teknikk (Jan 1978).

B. C. Research, Incorporated, "*Analysis of the Dynamics of a Motion Compensating Crane,*" (Jul 1976).

Bascomb, M. M., "*Environmental Analysis Relatrive to Portable Port Operations,*" Ocean Science and Engineering, Inc. (Nov 1969).

Battelle Columbus Laboratories, "*Deep Ocean Recovery System Vehicle Launch Crane, Summary Report,*" (Aug 1978).

Bechtel Corporation, "*Study of Mobile Emergency Port Facilities,*" Bechtel Corporation Report PB 184348 (Jun 1969).

Berkley, J. B. and N. F. Johnson, "*Engineering Report: San Diego Bay Tethered Float Breakwater,*" Ocean Technology Department, Naval Undersea Center (1976).

Bird, J. Dexter III, "*Preliminary Report Joint Army-Navy Rider Block Tagline System Test,*" EG&G Washington Analytical Services Center, Inc. (Dec 1977).

Bird, J. Dexter III, Dillon, D. B., Kahn, L. A., "*Analysis and Design of Impact Absorbers for Offshore Cranes,*" EG&G Washington Analytical Services Center, Inc. (Aug 1981).

Bird, J. Dexter III and Culpepper, William C., "*Rider Block Tagline Control System Evaluation,*" EG&G Washington Analytical Services Center, Inc. Report TR-D420-001 (Jun 1980).

Bird, J. Dexter III, "*Development of a Full Scale Platform Motion Compensator,*" EG&G Washington Analytical Services Center, Inc. Report TR-W2709-012 (Apr 1985).

Blagoveshchensky, S. N., "*Theory of Ship Motions,*" Dover Publications (1962).

Casler, R. and James A. Klein, "*The Application of Inertial Instrumentation to Improve the Performance of Marine Cranes and Offshore Cargo Handling Equipment,*" C. S. Draper Laboratory (undated).

Casler, R., F. Browne, E. Foster, J. Eterno, W. Podgorski, "*The Design of Control Systems to Aid Cargo-Transfer Operations in Moderate Seas (Final),*" C. S. Draper Laboratory Report R-1018 (Dec 1976).

Cecce, Robert F., "*Study to Determine the Feasibility of Installing a Rider Block System on Manitowoc 4100W Ringer Cranes and P & H 6250 Cranes,*" Epoch Engineering Report No. 361-1 (Mar 1977).

Clark, A. A., R. J. Lacavich, D. J. Brown, W. K. Dorbusch, R. W. Whalin, and F. B. Cox, "*Port Construction in the Theater of Operations,*" U. S. Army Engineering Waterways Experiment Station, Hydraulics Laboratory (Jun 1973).

Columbia Research Corporation, "*Installation of Rider Block Tagline System for Temporary Container Discharge System TECHEVAL and OPEVAL Tests,*" (undated).

Columbia Research Corporation, "*Sea Tests Barge Characteristics and Rider Block Tagline System (RBTS) Proof Tests S1 through S3 and S4B, S4C, S4D for Container Offloading and Transfer System (COTS),*" (30 May 1980).

Columbia Research Corporation, "*Tension Envelope of Rider Block Tagline System (RBTS) Container Offloading and Transfer System (COTS),*" (undated).

COMOPTEVFOR, "*Operational Evaluation of the Temporary Container Discharge Facility,*" (2 Apr 1981).

Crane, J. W. and C. A. Claudio, "*A Statistical Study of a Load Touchdown Algorithm for Use on The Test Bed Barge, JR-1,*" Naval Coastal Systems Center Technical Note 720-84 (Apr 1984).

Culpepper, William B., "*The Assessment of Damage to the T-ACS Rider Block Tagline Systems,*" Columbia Research Corporation (Aug 1985).

Dalby, M. C., M. B. Betts, C. D. Hansen, G. L. Brubaker, and L. F. Martin, "*A Methodology for Conducting Systems Analyses of Cargo Handling in Amphibious Ships in an Advanced Logistic Environment,*" P. Research, Inc. Report TN-219 (Jun 1972).

David Taylor Naval Ship Research and Development Center, "*Merchant Shipping and Transfer Craft Requirements in Support of Amphibious Operations,*" (Apr 1977).

Davis, D. A. and J. J. Traffalis, "*OSDOC II Crane Platform Productivity as a Function of Sea State,*" Civil Engineering Laboratory Report TM-55-77-6 (Jul 1977).

DeVries, H., W. P. Kaldenbach, and J. B. H. Suyderhoud, "*Design, Construction and Workability of a Semi-Submersible Derrick Barge with 2,000 Ton Revolving Crane,*" presented at Offshore Technology Conference, Paper Number OTC 3296 (May 1978).

Dobeck, Gerry J., "*A Control System Analysis for COTS Crane-On-Deck Configuration,*" NCSC (Mar 1979).

Duncan, J. H., R. H. Barr, and Y. Z. Liu, "*Computation of the Coupled Response of Two Bodies in a Seaway,*" paper presented at International Workshop on Ship and Platform Motions, UC-Berkeley, (26-28 Oct 1983).

Duncan, J. H. and C. E. Brown, "*Development of a Numerical Method for the Calculation of Power Absorption by Array of Similar Shaped Bodies in the Seaway,*" Journey of Ship Research, Vol 26, 1, pp. 38-44 (Mar 1982).

E. G. Frankel, Inc., "*Development of a Conceptual Design for Container Discharge Facility,*" Final Report, E. G. Frankel, Inc. Report No. 1039 (15 Apr 1972).

Essoglou, Milon E., "*Army-Navy Test of Offshore Discharge of Containership OSDOC I 5-9 December 1970,*" Naval Facilities Engineering Command (Jul 1971).

Estabrook, A. R., "*Afloat Container Drop Tests,*" NUC Report 1556, (Aug 1975).

Ford, Bacon & Davis Engineers (for NCEL), "*Report, Survey of Cranes Suitable for Use in a Temporary Container Discharge Facility,*" Vol. I - Test and Exhibits, Vol II - Appendix (30 Nov 1976).

Ford, Bacon, and Davis, Inc., "*Survey of Cranes Suitable for Use in a Temporary Container Discharge Facility,*" Civil Engineering Laboratory (Nov 1976).

Charrett, D. E. and A. M. Hyden, "*Dynamic Factors for Offshore Cranes,*" Offshore Technology Conference, Dallas, TX (1976).

Gardocki, M. J. and R. E. Mesloh, "*Physical Scale Modeling of Cranes, Final Report*" Battelle Columbus Laboratories Report NCSC-3 (Dec 1976).

General Electric Company, "*Design and Development of a Counter-Balance Winchdown Motion Compensating Cargo-Handling System for Loading Lighters at Shipside, Technical Proposal*" (Mar 1971).

Goodyear Aerospace Corporation, "*Crane Power Requirements Study for Cargo Transfer in Rough Seas,*" Goodyear Aerospace Corporation Report GER-16226 (May 1975).

Gunderson, S. R. and L. C. Ruth, "*An Investigation of the Relative and Absolute Ship Motions of Ship Involved in the OSDOC II Sea Trials,*" DTNSRDC Report SPD-515-01 (Nov 1976).

Gunderson, S. R. and L. C. Ruth, "*An Investigation of the Relative and Absolute Ship Motions of Ships Involved in the Offshore Discharge of Containership (OSDOC II) Sea Trials,*" NSRDC Report 515-H-01 (Mar 1973).

Hoffman, D., and V. K. Fitzgerald, "*Systems Approach to Offshore Crane Ship Operations,*" presented at SNAME Annual Meeting, New York, NY (1978).

Hydronautics, Inc., "*Predictions of Wave Induced Motions of TCDF Crane Barge,*" Hydronautics Report 7921-1 (May 1979).

Hydronautics, Inc., "*Model Tests of a Crane-Barge Combination,*" Hydronautics Report 7921-2 (1979).

IIT Research Institute, "*Dynamic Crane Derating Procedure Assessment IITRI Project J6372,*" (Jun 1976).

IIT Research Institute, "*Development of Rating and Dynamic Simulation Procedures for Shipboard Mobile Cranes, Final Technical Report,*" (Mar 1977).

J. J. Henry Company, "*Structural and Stability Study of the Crane on Deck (COD) and TCDF Concepts,*" J. J. Henry Report No. 1681-40-1 (Jan 1979).

J. J. Henry Company, "*LASH Amphibious Post-Assault Support (LAPS) Mission, Phase I - Conceptual Design Analysis,*" (1 Mar 1976).

J. J. Henry Company, "*Analysis of Containership Offloading at Advanced Operations Area,*" J. J. Henry Company (Aug 1975).

Johnson, Kenneth V., "*Theoretical Overload Factor-Effect of Sea State on Marine Cranes,*" Offshore Technology Conference, Houston, TX (1976).

Johnson, Kenneth V., "*Theoritical Overload Factor-Effect of Sea State on Marine Cranes,*" Offshore Technology Conference, Dallas, TX (1976).

Johnson, Frank R., Jr., "*Procedures for Determining Load Ratings for Truck Cranes Supported on a Floating Platform Moored in the Open Sea,*" CEL Report M-51-76-1 (Feb 1976).

Kaplan P. and R. R. Putz, "*The Motions of a Moored Construction Type Barge in Irregular Waves and Their Influence on Construction Operation,*" NCEL Report CR-62-8 (Aug 1962).

Keefer, B. G., "*Development of Motion Compensating Cranes for Rouch Sea Operations,*" Synopsis for Oceanology International, B. C. Research (1975).

Kinesman, Blair, "*Wind Waves: Their Generation and Propagation on the Ocean Surface,*" Prentice-Hall Publishing Co. (1963).

Kodan, N., "*The Motions of Adjacent Floating Structures in Oblique Waves,*" paper presented at ASME Third International Offshore Mechanics and Arctic Engineering Symposium, New Orleans, LA (Feb 1984).

Korsmeyer, F. T., "*T-ACS Offloading Mission Model Tests,*" Davidson Laboratory Report SIT-DL-83-9-2333 (Apr 1983).

Korvin-Kroukovsky, B. V., "*Theory of Seakeeping,*" The Society of Naval Architects and Marine Engineers (1961).

Kowalski, T., Ed., "*1974 Floating Breakwaters Conference Papers,*" National Oceanic and Atmospheric Administration, U. S. Department of Commerce (1974).

Kowalyshyn Robert, Roderick A. Barr, and Lewis R. Sheldon, "*Model Tests of a Crane-Barge Combination,*" Hydronautics, Inc. Report No. 7921-2 (Jun 1979).

Kraus, T. W., "*Automatic Cargo Transfer at Sea Using a Crane,*" C. S. Draper Laboratory Report No. T-713 (May 1980).

Kuperstein, D. W., "*Shipboard Craft and Cargo Handling Advanced Concepts, Final Report*" Hunters Point Naval Shipyard Report TN-20-70 (Nov 71).

Leonard, J. W., M. C Huang, and R. T. Hudspeth, "*Hydrodynamic Interference Between Floating Cylinders in Oblique Seas,*" Applied Ocean Research, Vol. 5, 2, pp. 159-166, (1983).

Lichty, D. W. and L. J. Proebstle, "*Cargo Transfer System,*" Goodyear IR&D Project No. 1505-75S1 (Dec 1975).

Lliff, K. W., "*Identification and Stochastic Control of an Aircraft Flying in Turbulence,*" Journal of Guidance and Control, Vol. I, No. 2 (Mar-Apr 1978).

Longuet-Higgins, M. S., "*On the Statistical Distribution of the Heights of Sea Waves,*" Journal of Marine Research, Vol. XI, No. 3 (1958).

McWethy, P. J., S. B. Nelson, ed., "*Handbook of Offshore Port Planning*," Marine Technology Society (1974).

Miller, R. W., T. C. Watson, D. W. Riggins, and C. M. Claudio, "*Ship Motion Analysis for the MOCOMP Program*," Naval Coastal Systems Center Technical Note 735-84 (Oct 1984).

Naval Weapons Station Earle, "*Report of Drop Test Container Offshore Transfer System (COTS) Technical Report*," NWHC Report 7967 (Dec 1979).

Naval Weapons Stations Earle, "*Drop Tests of an Aluminum ISO Commercial Container*," NWHL Report 7620 (Mar 1976).

Naval Electronics Laboratory Center, "*Profile for Open Ocean Crane Operators*," (undated).

NAVFAC, "*Container Offloading and Transfer (COTS) Airborne Interface Handbook*," (undated).

Navy Operational Test and Evaluation Force, "*OPTEVFOR Evaluation Report, Temporary Container Discharge Facility*," (Apr 1981).

NCEL, "*Summary of DT-II Tests for COTS Temporary Container Discharge Facility*," (May 1983).

NCEL, "*Estimates of Wave Induced Vertical Motion Between TCDF and COD Crane Booms and Receiving Lighterage*," (27 Feb 1975).

NCEL, "*COTS-TCDF Crane Program Swing Drive Test Failure Report*," (Jun 1979).

NCEL, "*Statis and Dynamic Stability of Crane Platforms*," (Mar 1975).

NCSC, "*Operations Handbook for Crane-On-Deck on Nonself-Sustaining Containerships*," (Nov 1980).

NCSC, "*Rider Block Tagline System COTS-TCDF Crane System Sea Tests S1-S3, S4B-S4D Note 4*," (30 May 1980).

NCSC, "*Operation and Maintenance Manual for Rider Block Tagline System (RBTS)*," (Nov 1980).

NCSC, "*Launch and Recovery Equipment for Shipborne Minehunting Sonar Systems (SMS)*," NCSC Report 07070-1-120-16069 (1 Dec 1975).

NCSC, "*Seaway Response of a Crane Mounted on a Type-B Delong Barge Under Various Crane Loading Conditions*," NCSC Report TM276-80, Copy 33 (Jan 1980).

NCSL, "*Preparation of Input Data for COTS Ship Motion Study,*" NCSL Report 415 (4 Apr 1977).

NCSL, "*Control Systems Model User's Manual for the Container Offloading and Transfer System (COTS),*" NCSL Report 413 (4 Aug 1977).

NOSC, "*Naval Ocean Systems Center Container Survivability Study Results of ISO Container Drop Tests on an LCU-Type Ship,*" NOSC Report TN-116 (May 1977).

Office of the Chief of Naval Operations, "*Operational Requirement for Auxiliary Crane Ship (TACS),*" Letter Ser 982F/358417 (16 Jul 1982).

OPTEVFOR, "*Temporary Container Discharge Facility - Evaluation Report,*" Navy Operational Test and Evaluation Force (Apr 1981).

ORI Incorporated, "*Logistics Over the Shore (LOTS),*" ORI Incorporated (Jan 1979).

Pope, W. S., J. M. Harris, A. M. Plummer, J. E. Drennan, and H. D. Harrison, "*Relative Motion Sensing Systems,*" Battelle Columbus Laboratories (Dec 1976).

Pope, W. S., J. M. Harris, A. M. Plummer, J. E. Drennan, and H. D. Harrison, "*Relative Motion Sensing Systems,*" Battelle Columbus Laboratories (Dec 1976).

Raichlen, Frederick, "*Hydrodynamic Analysis of a Tethered Float Breakwater,*" California Institute of Technology (Dec 1976).

Rucker Shaffer, "*200 Ton Crane Motion Compensator Product Description,*" Rucker Schaffer (Nov 1976).

Sayer, P., and R. Spencer, "*The Wave-Induced Motions of Adjacent Floating Vessels,*" paper presented at International Symposium on Hydrodynamics in Ocean Engineering at the Norwegian Institute of Technology (1981).

Scotch, J. P. and M. J. Gollobin, "*Crane-On-Deck (COD) Selection Process 009, Final,*" Presearch, Inc. Report No. 316 (29 Oct 76).

Sekita, K., H. Shimada, and M. Taniyama, "*The Operability of Derrick Barges in Construction of Large Offshore Structures,*" presented at Offshore Technology Conference, paper number OTC 2635, Houston, TX, (May 1976).

Seymour, R. J., "*Performance of Tethered Float Breakwaters in Deep Ocean Waves,*" California Department of Navigation and Ocean Development (Nov 1975).

Seymour, R. J., M. H. Sessions, and K. M. Wallace, "*Preliminary Report: Model Evaluation of Tethered Float Breakwaters,*" Institute of Marine Resources (Jul 1974).

Seymour, R. J., "*Performance of Tethered Float Breakwaters in Deep Ocean Waves,*" California Department of Navigation and Ocean Development (Nov 1975).

Society of Automotive Engineers (SAE), "*Rating Lift Cranes on Fixed Platforms Operating in the Ocean Environment - SAE J1238,*" (Handbook Supplement HS J1238) (Oct 1978).

Society of Automotive Engineers, "*Rating Lift Cranes on Floating Platforms Operating in the Ocean Environment - SAE XJ-1366,*" (1985).

St. Denis, Manley, "*Sea, Ships, Statistics,*" Ocean Wave Spectra, Prentice-Hall Publishing Co., New Jersey (1963).

Stout, G., M. Lyon (NCSC), and W. Culpepper (EG&G), "*Rider Block Tagline System Operation,*" NCSC and EG&G (Jan 1980).

Stout, G., J. Shelton, "*Rider Block Tagline System (RBTS) Installation, Disassembly, and Shipping,*" NSCS (Jan 1980).

Summey D. C. and T. C. Watson, "*Comparison of Computer Response Amplitide Operators for Containerships, Lighters, and Barges,*" NCSC Report TM 432-82 (Feb 1982).

Summey D. C. and T. C. Watson, "*Seaway Response of a Crane Mounted on a Type-B DeLong Barge Under Various Crane Loading Conditions,*" NCSC Report TM 276-80 (Jan 1980).

Sutherland, Arthur, Jr., "*Mechanical Systems for Ocean Engineering,*" NAVSEC (undated).

Techwest Enterprises (B. C. Research), "*Motion Compensating Winch Systems,*" (Apr 1977).

Techwest Enterprises, "*Final Report on the PMC-Winch Constant Tension Design Study,*" (Nov 1983).

Towne, R. C. and W. C. Hatch, "*Mooring System Concepts for Expeditionary Logistic Facility Operations,*" CEL Report TN-1196 (Oct 1971).

Traffalis, J. J., "*Container Offloading and Transfer System (COTS): Technical Evaluation of Temporary Container Discharge Facility (TCDF),*" NCEL Report TN-1625 (Mar 1982).

Traffalis, J. J., "*Power Tagline Development,*" NCEL (1 May 1975).

Tuten, James M., *"Reduction and Analysis of Data From Dynamic Loading Tests of American 9310 Crane, Final Report,"* Battelle Columbus Laboratories Report NCSC 5-1 (Sep 1979).

U. S. Department of Defense, *"Offshore Discharge of Containership II OSDOC II Test and Evaluation 3-14 October 1972,"* Evaluation Section, Joint Army-Navy Test Directorate (May 1973).

U. S. Department of the Army, *"Shore Protection Manual,"* U. S. Army Coastal Engineering Research Center (1973).

U. S. Department of the Navy, *"Merchant Ship Expeditionary Logistic Facility,"* Naval Ship Research and Development Center (Oct 1973).

U. S. Department of the Navy, *"Navy Decision Coordinating Paper for the Container Offloading and Transfer System (COTS),"* NDCP-YP816SL, Chief of Naval Operations (Jul 1975).

van Oortmerssen, G., *"Hydrodynamic Interaction Between Two Structures Floating in Waves,"* paper presented at Second International Conference on the Behavior of Offshore Structures, England, pp. 339-356, (1979).

van Oortmerssen G., *"Some Hydrodynamic Aspects of Multi-Body Systems,"* paper presented at International Symposium on Hydrodynamics in Ocean Engineering, Norway, pp. 724-744, (1981).

Wang, S. S., *"Crane Load Decoupler for the Elevated Causeway (ELCAS),"* Naval Facilities Engineering Command (Dec 1984).

Welch, R. E. and A. Lo, *"CWA Project 4006, Summary Report Dynamic Analysis and Testing of Barge Mounted Construction Cranes,"* CEL (Jul 1979).

Welsh R. E., F. J. Vyzral, E. Hahn, *"Development of Ratings and Dynamic Simulation Procedures for Shipboard Mobile Cranes, Second Interim Technical Report,"* Synamic Simulation Procedures, IIT Research Institute Report J6381 (Nov 1976).

Yumori, I. R., *"Ocean Testing of Motion Compensating Crane and Kevlar Tether Cable Dynamics for an Unmanned Deep Submersible Using Real Time Spectral Analysis,"* Oceans (Sep 1979).

Zwibel, H. S. and D. A. Davis, *"Cargo Transfer at Sea - The Pendulation of Loads Suspended from Ship-Board Cranes,"* NCEL (Dec 1972).

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